FIG. 1

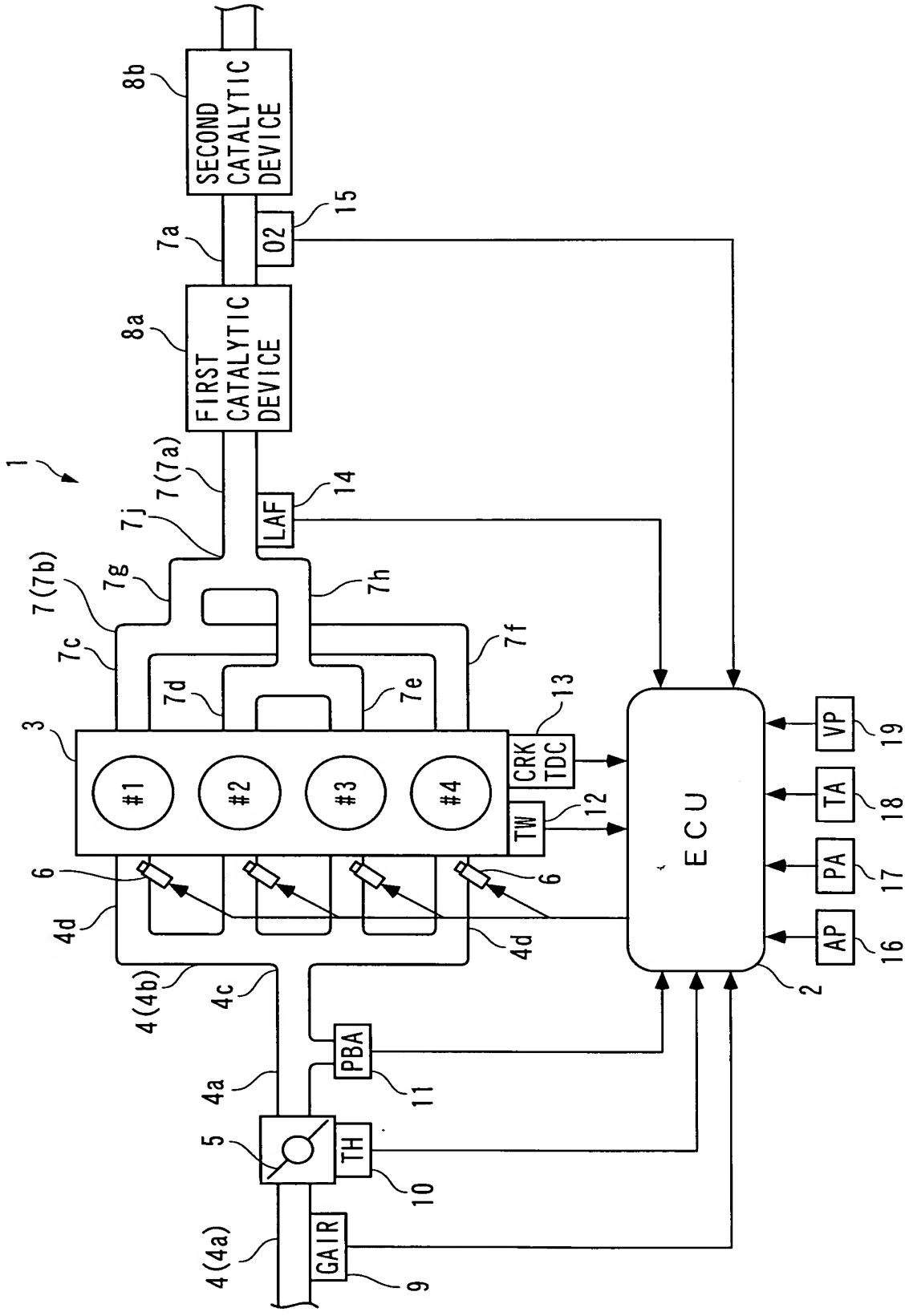
SECOND CATALYTIC DEVICE
FIRST CATALYTIC DEVICE
O2
LAF
ECU
CRK
TDC
TW
TH
PBA
GAIR
VP
TA
PA
AP
#1
#2
#3
#4
1
2
3
4(4a)
4(4b)
4a
4c
4d
5
6
7(7a)
7(7b)
7a
7c
7d
7e
7f
7g
7h
7j
8a
8b
9
10
11
12
13
14
15
16
17
18
19

FIG. 2

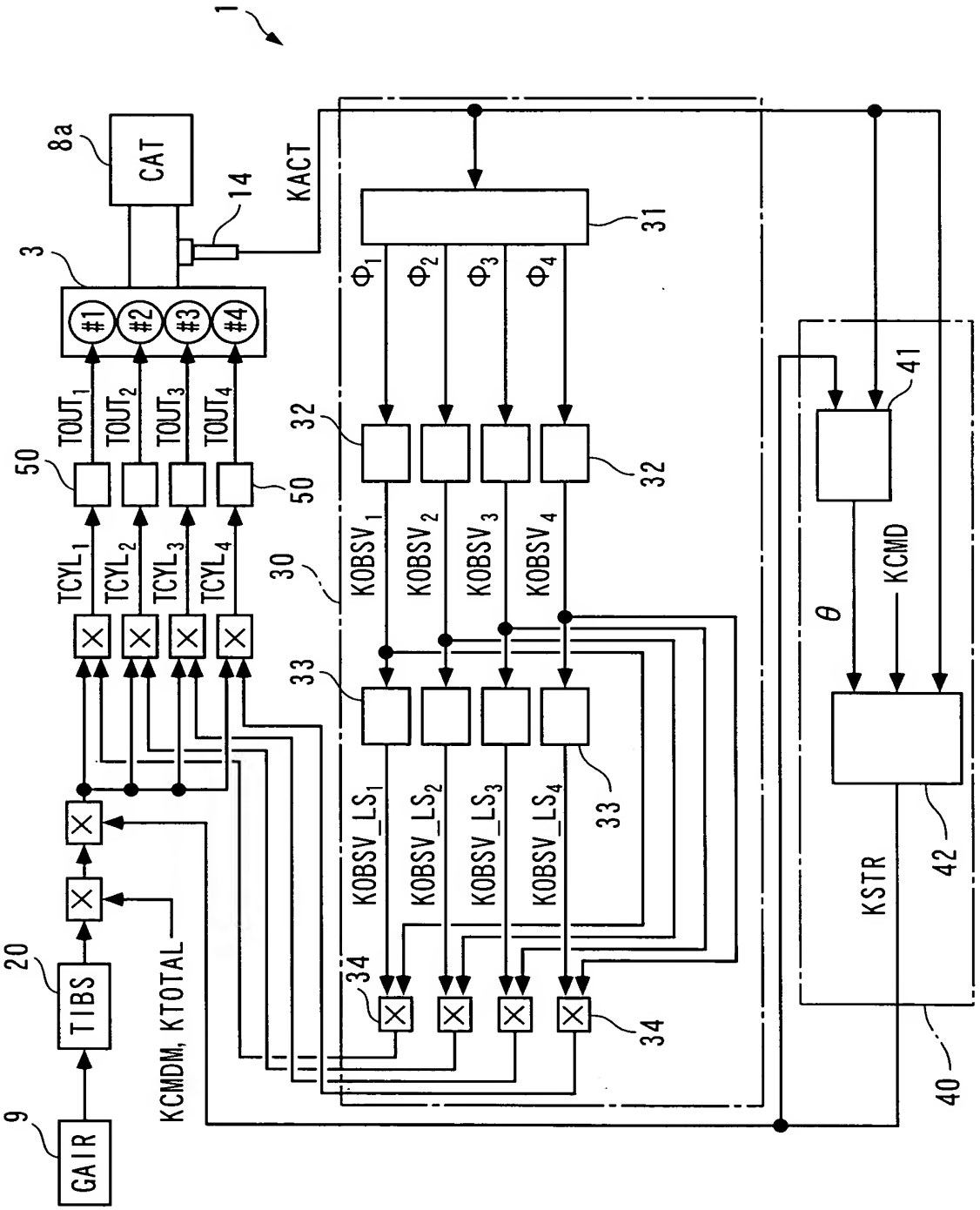
1
8a
CAT
14
KACT
3
#1
#2
#3
#4
31
Φ1
Φ2
Φ3
Φ4
TOUT1
TOUT2
TOUT3
TOUT4
50
32
41
TCYL1
TCYL2
TCYL3
TCYL4
30
KOBSV1
KOBSV2
KOBSV3
KOBSV4
θ
KCMD
33
KOBSV_LS1
KOBSV_LS2
KOBSV_LS3
KOBSV_LS4
20
TIBS
KCMDM, KTOTAL
34
KSTR
42
9
GAIR
40

FIG. 3

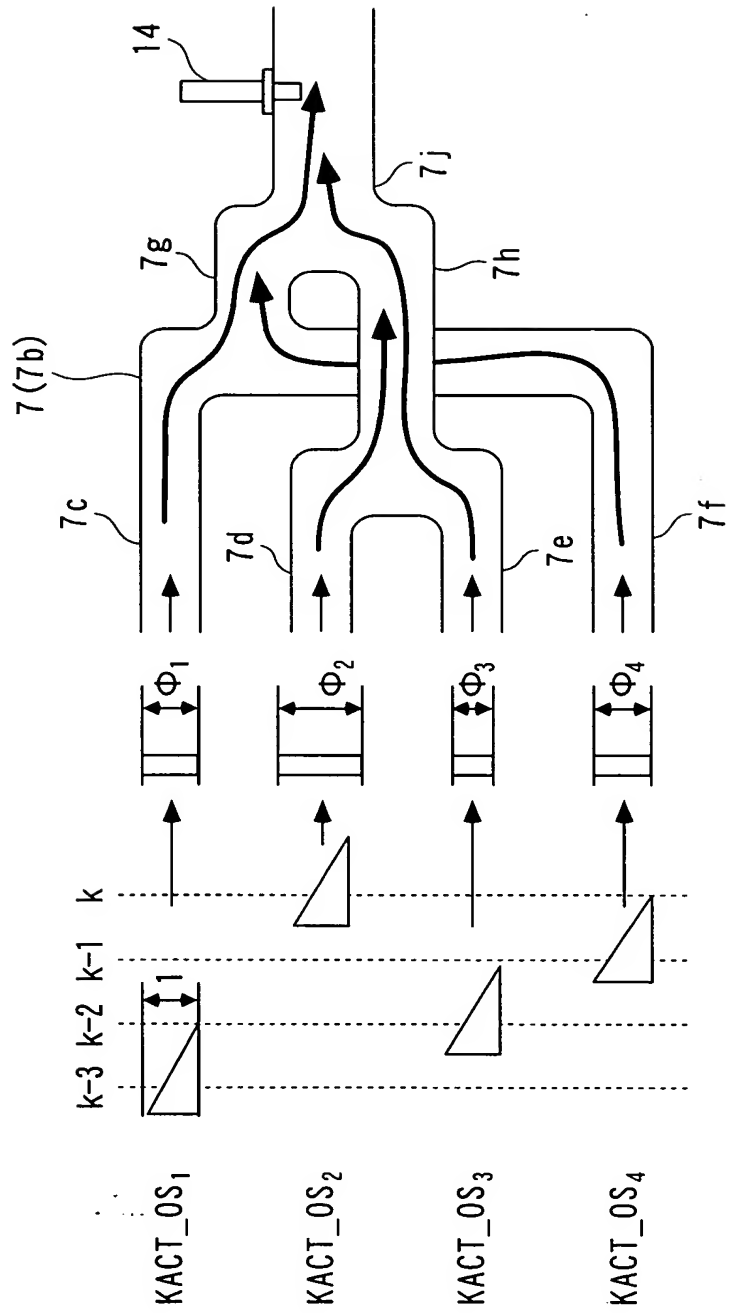
14
7j
7g
7h
7(7b)
7c
7d
7e
7f
Φ1
Φ2
Φ3
Φ4
k
k-1
k-2
k-3
1
KACT_OS1
KACT_OS2
KACT_OS3
KACT_OS4

FIG. 4

$$KACT(k)=\Phi_1(k)\cdot KACT\_OS_1(k-d)+\Phi_2(k)\cdot KACT\_OS_2(k-d)+\Phi_3(k)\cdot KACT\_OS_3(k-d)+\Phi_4(k)\cdot KACT\_OS_4(k-d) \quad \cdots\cdots (1)$$

$$KACT\_EST(k)=\Phi_1(k)\cdot KACT\_OS_1(k-d)+\Phi_2(k)\cdot KACT\_OS_2(k-d)+\Phi_3(k)\cdot KACT\_OS_3(k-d)+\Phi_4(k)\cdot KACT\_OS_4(k-d) \quad \cdots\cdots (2)$$

$$\phi(k)=\phi(k-1)+KP(k)\cdot ide(k) \quad \cdots\cdots (3)$$

$$\phi(k)^T=[\Phi_1(k),\ \Phi_2(k),\ \Phi_3(k),\ \Phi_4(k)] \quad \cdots\cdots (4)$$

$$ide(k)=KACT(k)-KACT\_EST(k) \quad \cdots\cdots (5)$$

$$KACT\_EST(k)=\phi(k-1)^T\cdot\zeta(k) \quad \cdots\cdots (6)$$

$$\zeta(k)^T=[KACT\_OS_1(k-d),\ KACT\_OS_2(k-d),\ KACT\_OS_3(k-d),\ KACT\_OS_4(k-d)] \quad \cdots\cdots (7)$$

$$KP(k)=\frac{P(k)\cdot\zeta(k)}{1+\zeta(k)^T\cdot P(k)\cdot\zeta(k)} \quad \cdots\cdots (8)$$

$$P(k+1)=\frac{1}{\lambda_1}\left(I-\frac{\lambda_2\cdot P(k)\cdot\zeta(k)\cdot\zeta(k)^T}{\lambda_1+\lambda_2\cdot\zeta(k)^T\cdot P(K)\cdot\zeta(k)}\right)P(k) \quad \cdots\cdots (9)$$

I : UNIT MATRIX

λ_1, λ_2 : WEIGHTING PARAMETER

FIG. 5

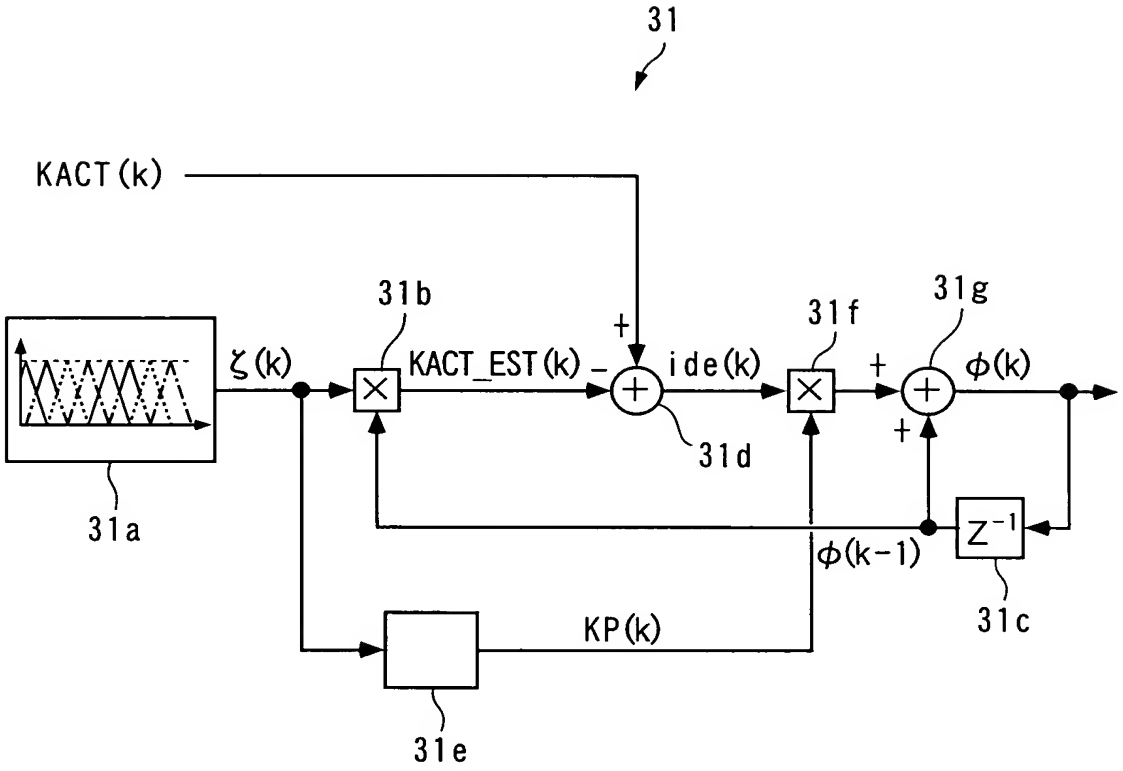
31
KACT(k)
31b
31f
31g
+
ζ(k)
KACT_EST(k)
−
ide(k)
+
φ(k)
+
31d
31a
Z⁻¹
φ(k-1)
31c
KP(k)
31e

FIG. 6

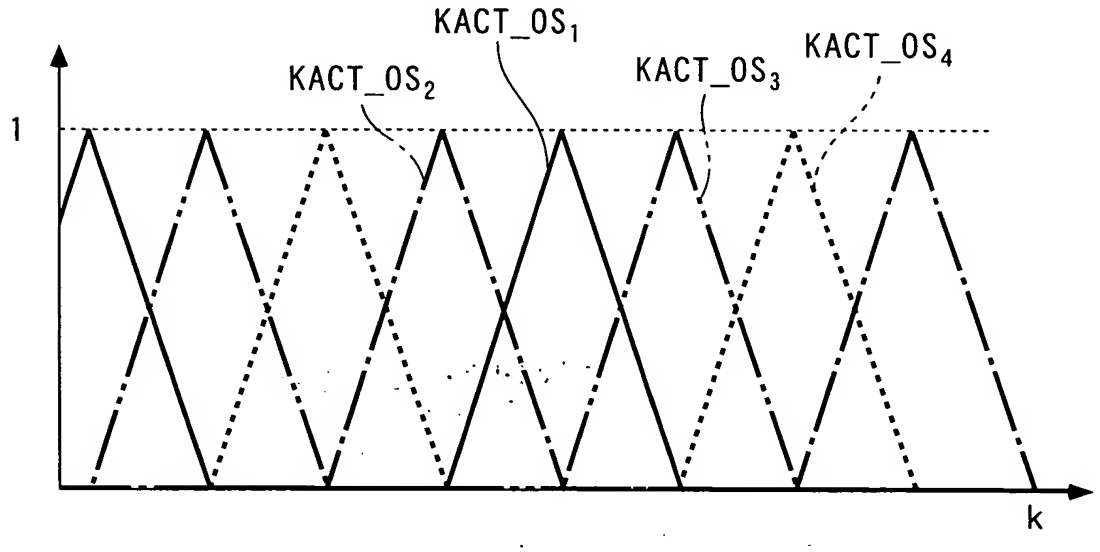
KACT_OS1
KACT_OS2
KACT_OS3
KACT_OS4
1
k

FIG. 7

$$\Phi ave(k) = \frac{1}{4} \cdot \left\{ \Phi_1(k) + \Phi_2(k) + \Phi_3(k) + \Phi_4(k) \right\} \quad \cdots\cdots (10)$$

$$KOBSV_i(k) = -GI \cdot \sum_{j=0}^{k} e(j) - FI \cdot \Phi_i(k) - HI \cdot [\Phi_i(k) - \Phi_i(k-1)] \quad \cdots\cdots (11)$$

$$e(k) = \Phi_i(k) - \Phi ave(k) \quad \cdots\cdots (12)$$

FI, GI, HI : FEEDBACK GAINS

FIG. 8A

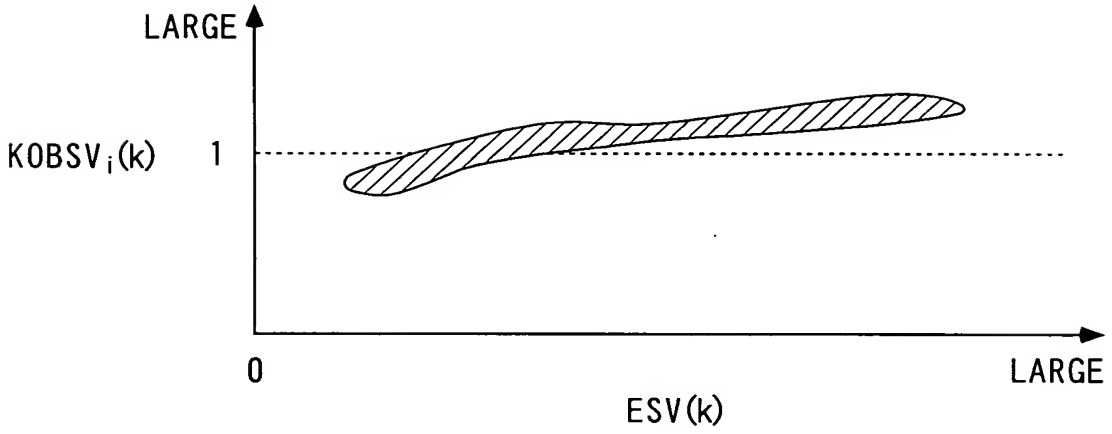
LARGE
KOBSV$_i$(k)
1
0
LARGE
ESV(k)

FIG. 8B

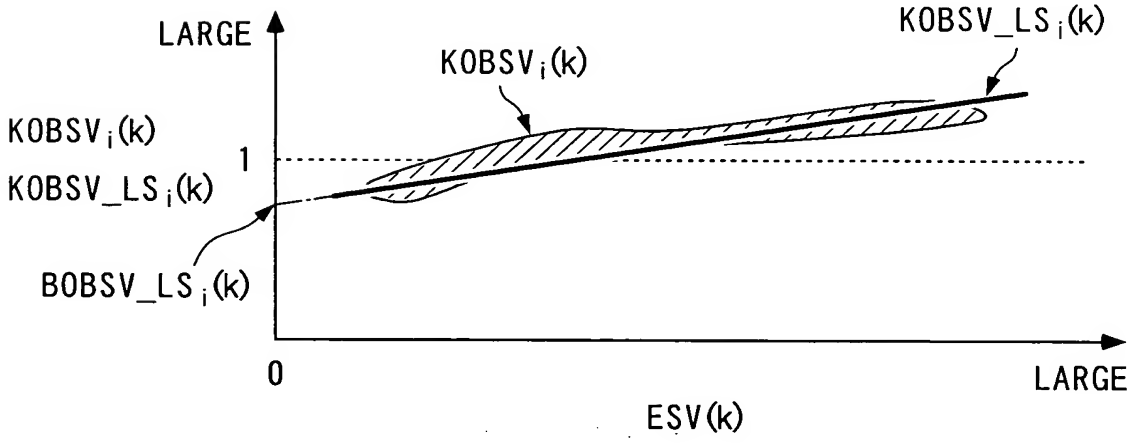
LARGE
KOBSV_LS$_i$(k)
KOBSV$_i$(k)
KOBSV$_i$(k)
1
KOBSV_LS$_i$(k)
BOBSV_LS$_i$(k)
0
LARGE
ESV(k)

FIG. 9

$$ESV(k) = \frac{NE(k)}{1500} \cdot PBA(k) \cdot SVPRA \quad \cdots\cdots (13)$$

$$KOBSV\_LS_i(k) = AOBSV\_LS_i \cdot ESV(k) + BOBSV\_LS_i \quad \cdots\cdots (14)$$

$$\theta OBSV\_LS_i(k) = \theta OBSV\_LS_i(k-1) + KQ_i(k) \cdot Eov_i(k) \quad \cdots\cdots (15)$$

$$\theta OBSV\_LS_i(k)^T = [AOBSV\_LS_i(k), BOBSV\_LS_i(k)] \quad \cdots\cdots (16)$$

$$Eov_i(k) = KOBSV_i(k) \cdot KOBSV\_LS_i(k) - \theta OBSVLS_i(k-1)^T \cdot Z(k) \quad \cdots\cdots (17)$$

$$KOBSV\_LS_i(k) = \theta OBSV\_LS_i(k-1)^T \cdot Z(k) \quad \cdots\cdots (18)$$

$$Z(k)^T = [ESV(k), 1] \quad \cdots\cdots (19)$$

$$KQ_i(k) = \frac{Q_i(k) \cdot Z(k)}{1 + Z(k)^T \cdot Q_i(k) \cdot Z(k)} \quad \cdots\cdots (20)$$

$$Q_i(k+1) = \frac{1}{\lambda_1'} \cdot \left(I - \frac{\lambda_2' \cdot Q_i(k) \cdot Z(k)^T \cdot Z(k)}{\lambda_1' + \lambda_2' \cdot Z(k)^T \cdot Q_i(k) \cdot Z(k)} \right) \cdot Q_i(k) \quad \cdots\cdots (21)$$

I : UNIT MATRIX

λ_1', λ_2' : WEIGHTING PARAMETER

$$KOBSV\_LS_i(k) = \hat{\theta OBSV\_LS_i}(k-1)^T \cdot Z(k) = AOBSV\_LS_i(k-1) \cdot ESV(k) + BOBSV\_LS_i(k-1) \quad \cdots\cdots (22)$$

FIG. 10

$$KACT(n) = b0(n) \cdot KSTR(n-3) + r1(n) \cdot KSTR(n-4) + r2(n) \cdot KSTR(n-5) + r3(n) \cdot KSTR(n-6) + s0(n) \cdot KACT(n-3) \quad \cdots\cdots (23)$$

$$KSTR(n) = \frac{1}{b0(n)} \cdot \{KCMD(n) - r1(n) \cdot KSTR(n-1) - r2(n) \cdot KSTR(n-2) - r3(n) \cdot KSTR(n-3) - s0(n) \cdot KACT(n)\} \quad \cdots\cdots (24)$$

$$\theta(n) = \theta(n-1) + K\Gamma(n) \cdot ide\_st(n) \quad \cdots\cdots (25)$$

$$\theta(n)^T = [b0(n),\ r1(n),\ r2(n),\ r3(n),\ s0(n)] \quad \cdots\cdots (26)$$

$$ide\_st(n) = KACT(n) - KACT\_HAT(n) \quad \cdots\cdots (27)$$

$$KACT\_HAT(n) = \theta(n-1)^T \cdot \xi(n) \quad \cdots\cdots (28)$$

$$\xi(n)^T = [KSTR(n-3),\ KSTR(n-4),\ KSTR(n-5),\ KSTR(n-6),\ KACT(n-3)] \quad \cdots\cdots (29)$$

$$K\Gamma(n) = \frac{\Gamma(n) \cdot \xi(n)}{1 + \xi(n)^T \cdot \Gamma(n) \cdot \xi(n)} \quad \cdots\cdots (30)$$

$$\Gamma(n+1) = \frac{1}{\lambda_{1S}} \left(I - \frac{\lambda_{2S} \cdot \Gamma(n) \cdot \xi(n) \cdot \xi(n)^T}{\lambda_{1S} + \lambda_{2S} \cdot \xi(n)^T \cdot \Gamma(n) \cdot \xi(n)} \right) \Gamma(n) \quad \cdots\cdots (31)$$

I : UNIT MATRIX

$\lambda_{1S}, \lambda_{2S}$: WEIGHTING PARAMETER

FIG. 11

$$\theta\_ave(k) = \frac{1}{m+1}\{\theta buf(k) + \cdots + \theta buf(k-m)\} \quad \cdots\cdots (32)$$

$$\theta\_ave(k)^T = [b0\_ave(k),\ r1\_ave(k),\ r2\_ave(k),\ r3\_ave(k),\ s0\_ave(k)] \quad \cdots\cdots (33)$$

$$KSTR(k) = \frac{1}{b0\_ave(k)} \cdot \Big\{KCMD(k) - r1\_ave(k)\cdot KSTR(k-4) - r2\_ave(k)KSTR(k-8) - r3\_ave(k)\cdot KSTR(k-12) - s0\_ave(k)\cdot KACT(k)\Big\} \quad \cdots\cdots (34)$$

$$\theta(n) = \theta(n-1) + K\Gamma(n)\cdot ide\_st(n) \quad \cdots\cdots (35)$$

$$\theta(n)^T = [b0(n),\ r1(n),\ r2(n),\ r3(n),\ s0(n)] \quad \cdots\cdots (36)$$

$$ide\_st(n) = KACT(n) - KACT\_HAT(n) \quad \cdots\cdots (37)$$

$$KACT\_HAT(n) = \theta(n-1)^T \cdot \xi(n) \quad \cdots\cdots (38)$$

$$\xi(n)^T = [KSTR(n-3),\ KSTR(n-4),\ KSTR(n-5),\ KSTR(n-6),\ KACT(n-3)]$$
$$= [KSTR(k-12), KSTR(k-16), KSTR(k-20), KSTR(k-24), KACT(k-12)] \quad \cdots\cdots (39)$$

$$K\Gamma(n) = \frac{\Gamma(n)\cdot\xi(n)}{1+\xi(n)^T\cdot\Gamma(n)\cdot\xi(n)} \quad \cdots\cdots (40)$$

$$\Gamma(n+1) = \frac{1}{\lambda_{1S}}\left(I - \frac{\lambda_{2S}\cdot\Gamma(n)\cdot\xi(n)\cdot\xi(n)^T}{\lambda_{1S}+\lambda_{2S}\cdot\xi(n)^T\cdot\Gamma(n)\cdot\xi(n)}\right)\Gamma(n) \quad \cdots\cdots (41)$$

I : UNIT MATRIX
$\lambda_{1S}, \lambda_{2S}$: WEIGHTING PARAMETER

FIG. 12

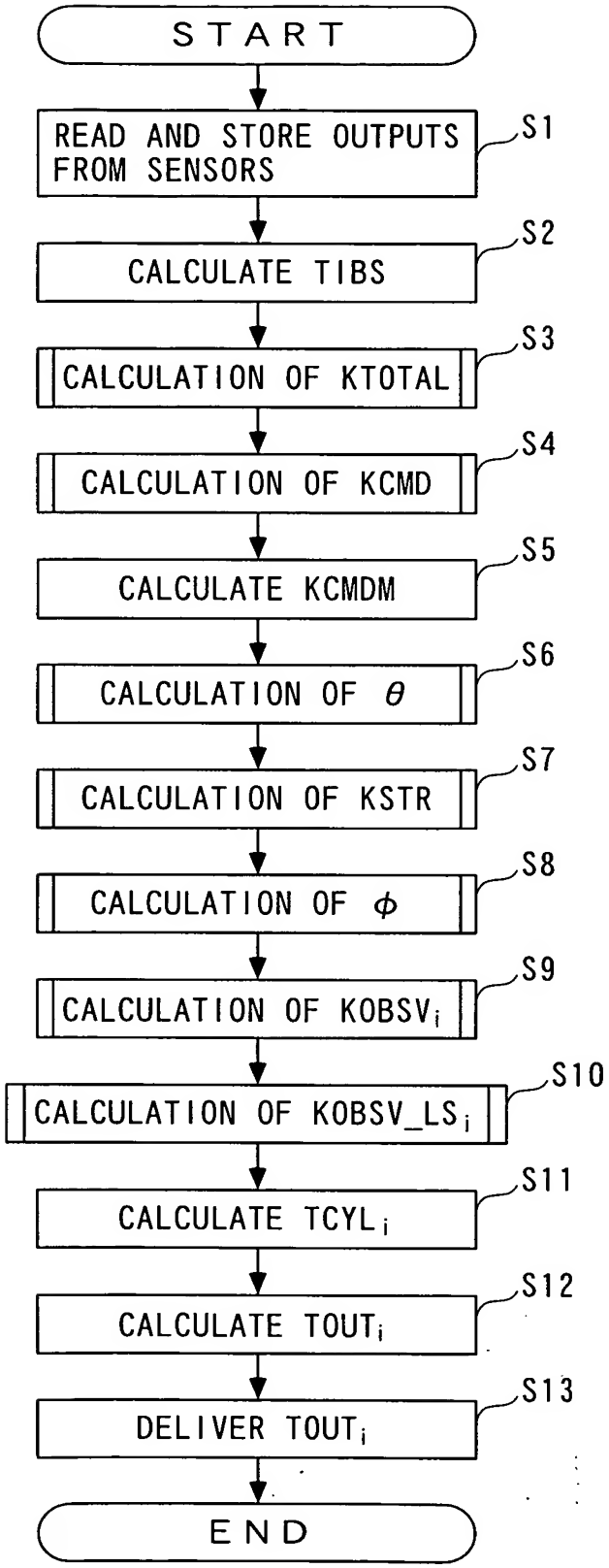
START
READ AND STORE OUTPUTS FROM SENSORS
S1
CALCULATE TIBS
S2
CALCULATION OF KTOTAL
S3
CALCULATION OF KCMD
S4
CALCULATE KCMDM
S5
CALCULATION OF θ
S6
CALCULATION OF KSTR
S7
CALCULATION OF φ
S8
CALCULATION OF KOBSV$_i$
S9
CALCULATION OF KOBSV_LS$_i$
S10
CALCULATE TCYL$_i$
S11
CALCULATE TOUT$_i$
S12
DELIVER TOUT$_i$
S13
END

FIG. 13

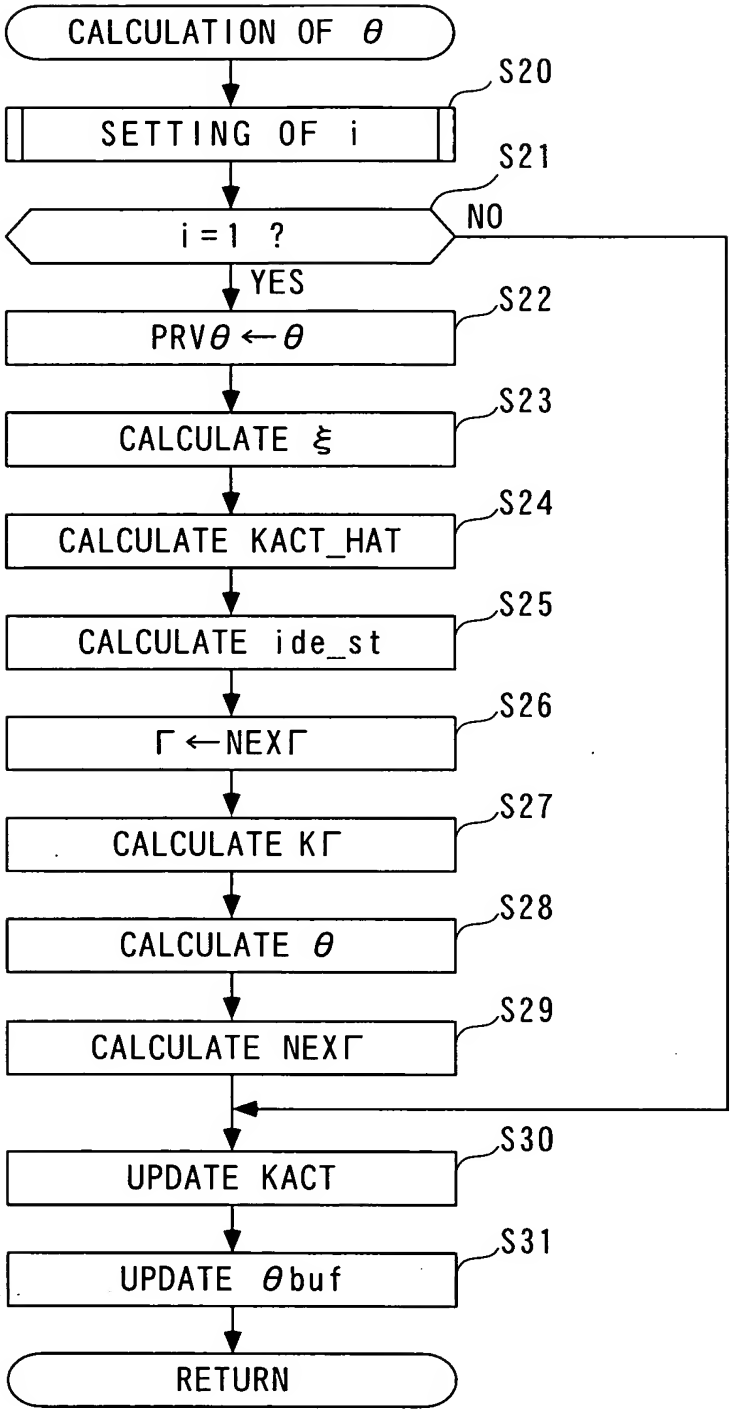
CALCULATION OF θ
S20
SETTING OF i
S21
i=1 ?
NO
YES
S22
PRVθ←θ
S23
CALCULATE ξ
S24
CALCULATE KACT_HAT
S25
CALCULATE ide_st
S26
Γ←NEXΓ
S27
CALCULATE KΓ
S28
CALCULATE θ
S29
CALCULATE NEXΓ
S30
UPDATE KACT
S31
UPDATE θbuf
RETURN

FIG. 14

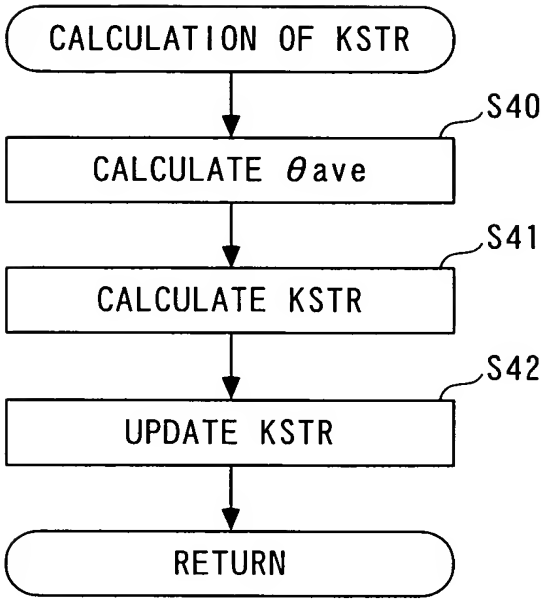
CALCULATION OF KSTR
S40
CALCULATE θave
S41
CALCULATE KSTR
S42
UPDATE KSTR
RETURN

FIG. 15

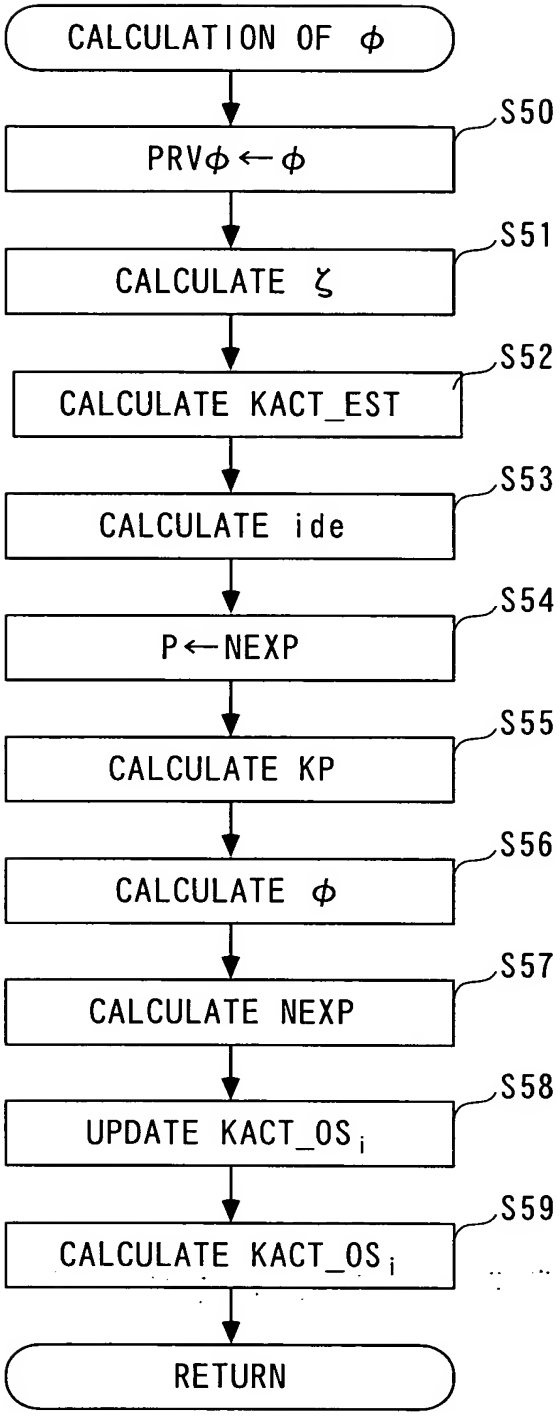
CALCULATION OF φ
S50
PRVφ←φ
S51
CALCULATE ζ
S52
CALCULATE KACT_EST
S53
CALCULATE ide
S54
P←NEXP
S55
CALCULATE KP
S56
CALCULATE φ
S57
CALCULATE NEXP
S58
UPDATE KACT_OS$_i$
S59
CALCULATE KACT_OS$_i$
RETURN

FIG. 16

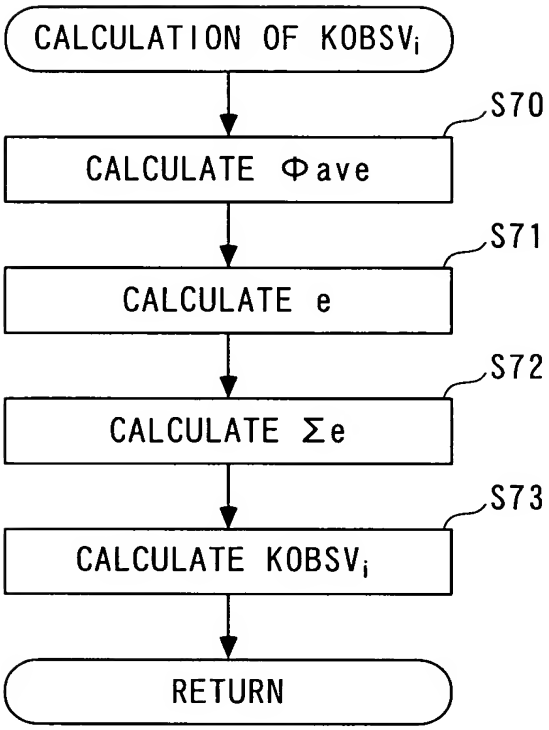
CALCULATION OF KOBSV$_i$
S70
CALCULATE Φave
S71
CALCULATE e
S72
CALCULATE Σe
S73
CALCULATE KOBSV$_i$
RETURN

FIG. 17

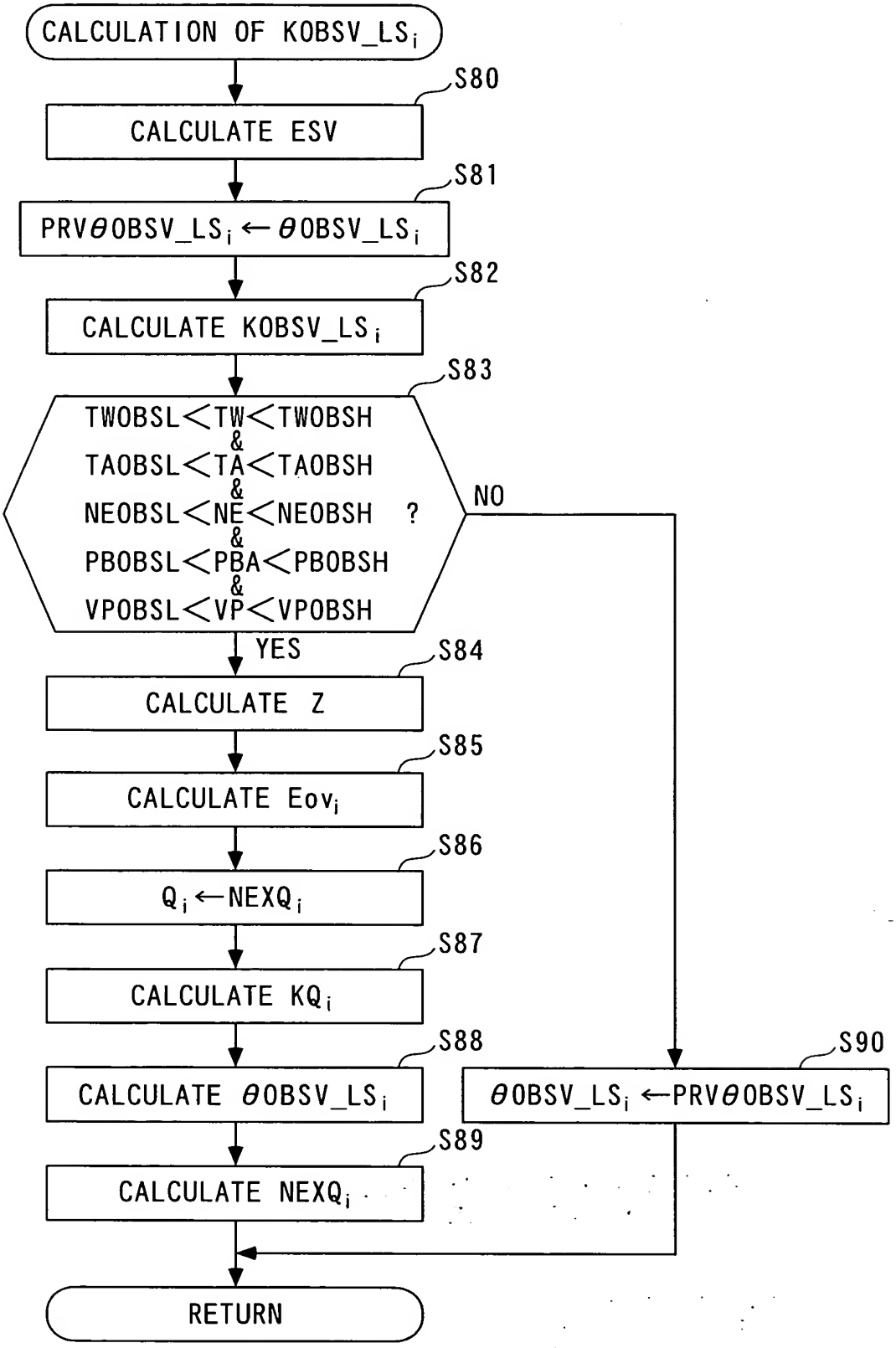
CALCULATION OF KOBSV_LSi
S80
CALCULATE ESV
S81
PRVθOBSV_LSi ← θOBSV_LSi
S82
CALCULATE KOBSV_LSi
S83
TWOBSL<TW<TWOBSH
&
TAOBSL<TA<TAOBSH
&
NEOBSL<NE<NEOBSH ?
&
PBOBSL<PBA<PBOBSH
&
VPOBSL<VP<VPOBSH
NO
YES
S84
CALCULATE Z
S85
CALCULATE Eovi
S86
Qi ← NEXQi
S87
CALCULATE KQi
S88
CALCULATE θOBSV_LSi
S89
CALCULATE NEXQi
S90
θOBSV_LSi ← PRVθOBSV_LSi
RETURN

FIG. 18

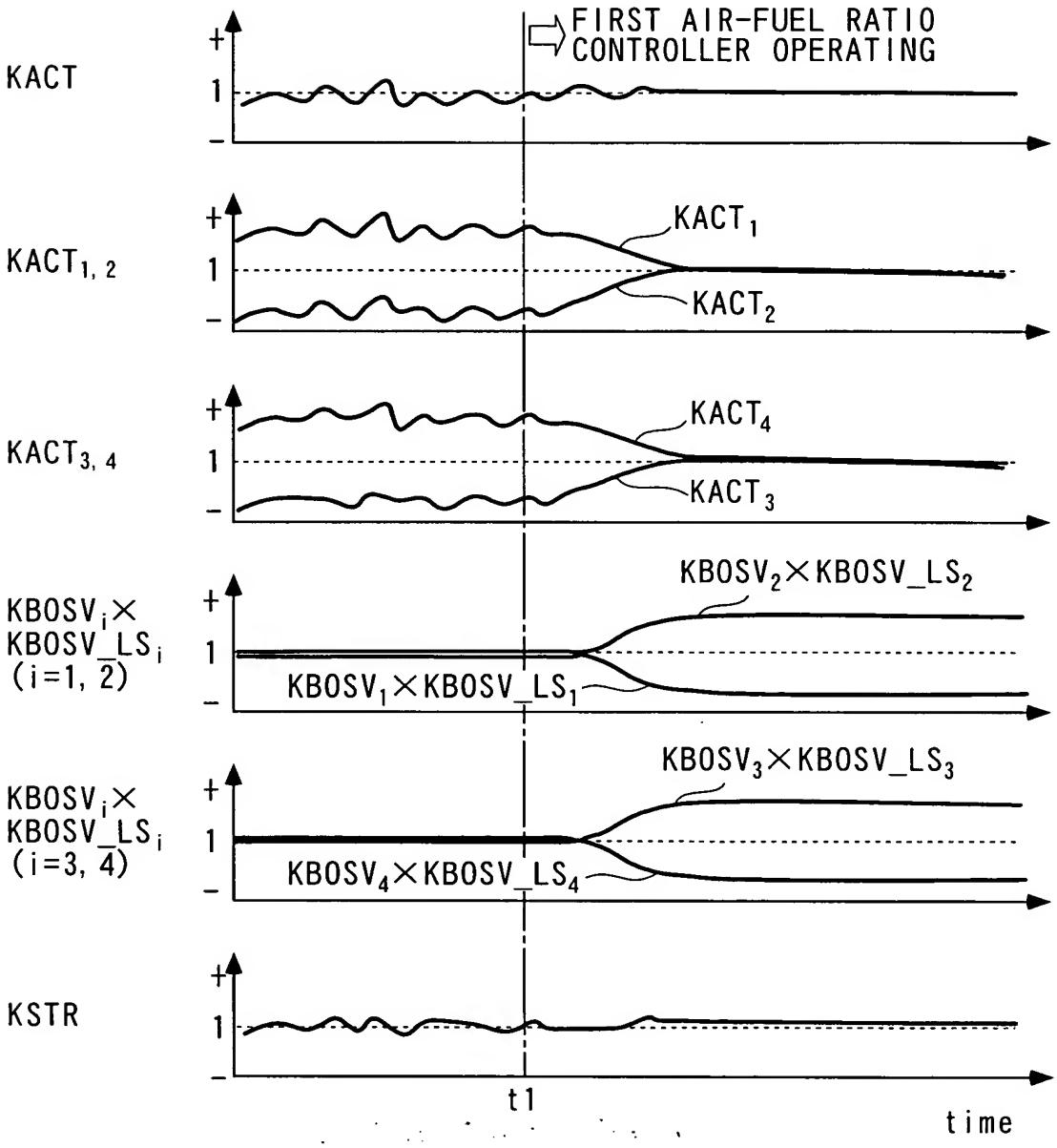
KACT
FIRST AIR-FUEL RATIO CONTROLLER OPERATING
KACT1, 2
KACT1
KACT2
KACT3, 4
KACT4
KACT3
KBOSVi×KBOSV_LSi (i=1, 2)
KBOSV2×KBOSV_LS2
KBOSV1×KBOSV_LS1
KBOSVi×KBOSV_LSi (i=3, 4)
KBOSV3×KBOSV_LS3
KBOSV4×KBOSV_LS4
KSTR
+
1
−
t1
time

FIG. 19

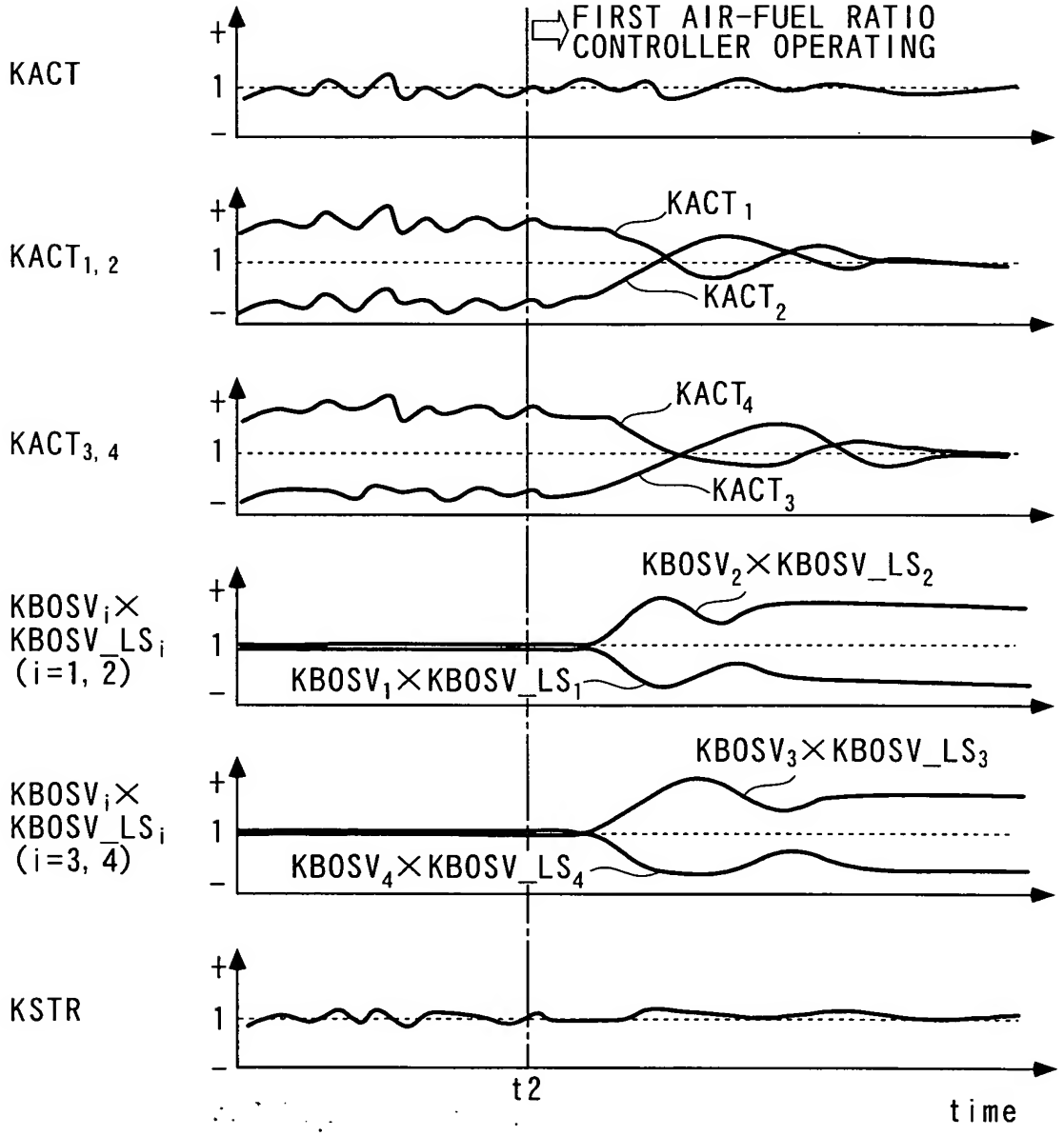
KACT
FIRST AIR-FUEL RATIO CONTROLLER OPERATING
+
1
−
KACT1, 2
KACT1
KACT2
KACT3, 4
KACT4
KACT3
KBOSVi×KBOSV_LSi (i=1, 2)
KBOSV2×KBOSV_LS2
KBOSV1×KBOSV_LS1
KBOSVi×KBOSV_LSi (i=3, 4)
KBOSV3×KBOSV_LS3
KBOSV4×KBOSV_LS4
KSTR
t2
time

FIG. 20

PID CONTROL ALGORITHM

$$KOBSV_i(k) = -GP \cdot \sum_{j=0}^{k} \cdot e_i(j) - FP \cdot e_i(k) - HP \cdot [e_i(k) - e_i(k-1)] \quad \cdots\cdots (43)$$

$$e_i(k) = \Phi_i(k) - \Phi ave(k) \quad \cdots\cdots (44)$$

FP, GP, HP : FEEDBACK GAINS

IP-D CONTROL ALGORITHM

$$KOBSV_i(k) = -GD \cdot \sum_{j=0}^{k} e(j) - FD \cdot e(k) - HD \cdot [\Phi_i(k) - \Phi_i(k-1)] \quad \cdots\cdots (45)$$

$$e(k) = \Phi_i(k) - \Phi ave(k) \quad \cdots\cdots (46)$$

FD, GD, HD : FEEDBACK GAINS

RESPONSE-SPECIFIED CONTROL ALGORITHM

$$KOBSV_i(k) = -FS \cdot \sigma(k) - GS \cdot \sum_{j=0}^{k} \cdot \sigma(j) - HS \cdot e(k) \quad \cdots\cdots (47)$$

$$e(k) = \Phi_i(k) - \Phi ave(k) \quad \cdots\cdots (48)$$

$$\sigma(k) = e(k) + S \cdot e(k-1) \quad \cdots\cdots (49)$$

$\sigma(k)$: SWITCHING FUNCTION
FS, GS, HS : FEEDBACK GAINS
S : SWITCHING FUNCTION SETTING PARAMETER ($-1 < S < 1$)

FIG. 21

$$\phi(k)=\phi base+d\phi(k) \quad \cdots\cdots (50)$$

$$\phi base^{T}=[\Phi base_1,\ \Phi base_2,\ \Phi base_3,\ \Phi base_4] \quad \cdots\cdots (51)$$

$$d\phi(k)=\delta\cdot d\phi(k-1)+KP(k)\cdot ide(k) \quad \cdots\cdots (52)$$

$$ide(k)=KACT(k)-KACT\_EST(k) \quad \cdots\cdots (53)$$

$$KACT\_EST(k)=\phi(k-1)^{T}\cdot\zeta(k) \quad \cdots\cdots (54)$$

$$\zeta(k)^{T}=[KACT\_OS_1(k-d),\ KACT\_OS_2(k-d),\ KACT\_OS_3(k-d),\ KACT\_OS_4(k-d)] \quad \cdots\cdots (55)$$

$$KP(k)=\frac{Pc\cdot\zeta(k)}{1+\zeta(k)^{T}\cdot Pc\cdot\zeta(k)} \quad \cdots\cdots (56)$$

Pc : IDENTIFICATION GAIN

$$\delta=\begin{bmatrix}\delta 1 & 0 & 0 & 0\\ 0 & \delta 1 & 0 & 0\\ 0 & 0 & \delta 1 & 0\\ 0 & 0 & 0 & \delta 1\end{bmatrix}\quad (0<\delta 1\leqq 1) \quad \cdots\cdots (57)$$

δ : FORGETTING VECTOR

FIG. 22

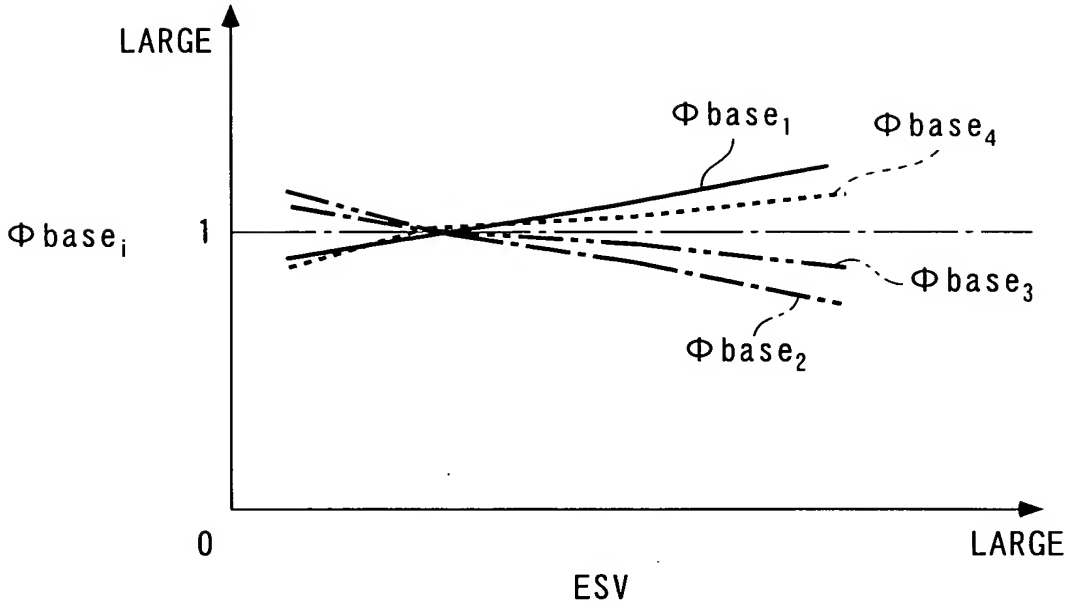

FIG. 23

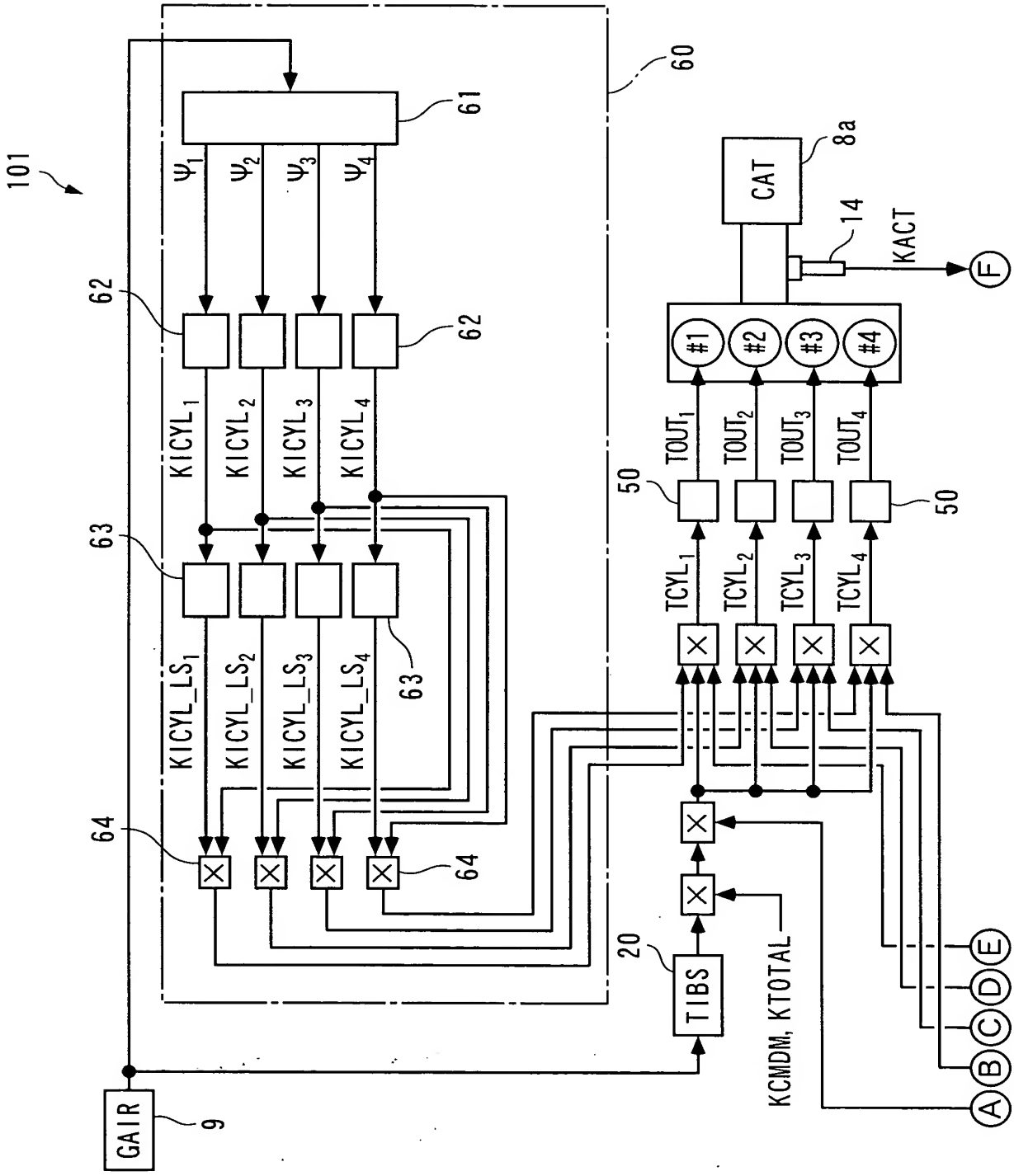
101
60
61
62
63
64
50
20
9
8a
14
CAT
KACT
GAIR
TIBS
KCMDM, KTOTAL
ψ_1 ψ_2 ψ_3 ψ_4
$KICYL_1$ $KICYL_2$ $KICYL_3$ $KICYL_4$
$KICYL\_LS_1$ $KICYL\_LS_2$ $KICYL\_LS_3$ $KICYL\_LS_4$
$TCYL_1$ $TCYL_2$ $TCYL_3$ $TCYL_4$
$TOUT_1$ $TOUT_2$ $TOUT_3$ $TOUT_4$
#1 #2 #3 #4
Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ

FIG. 24

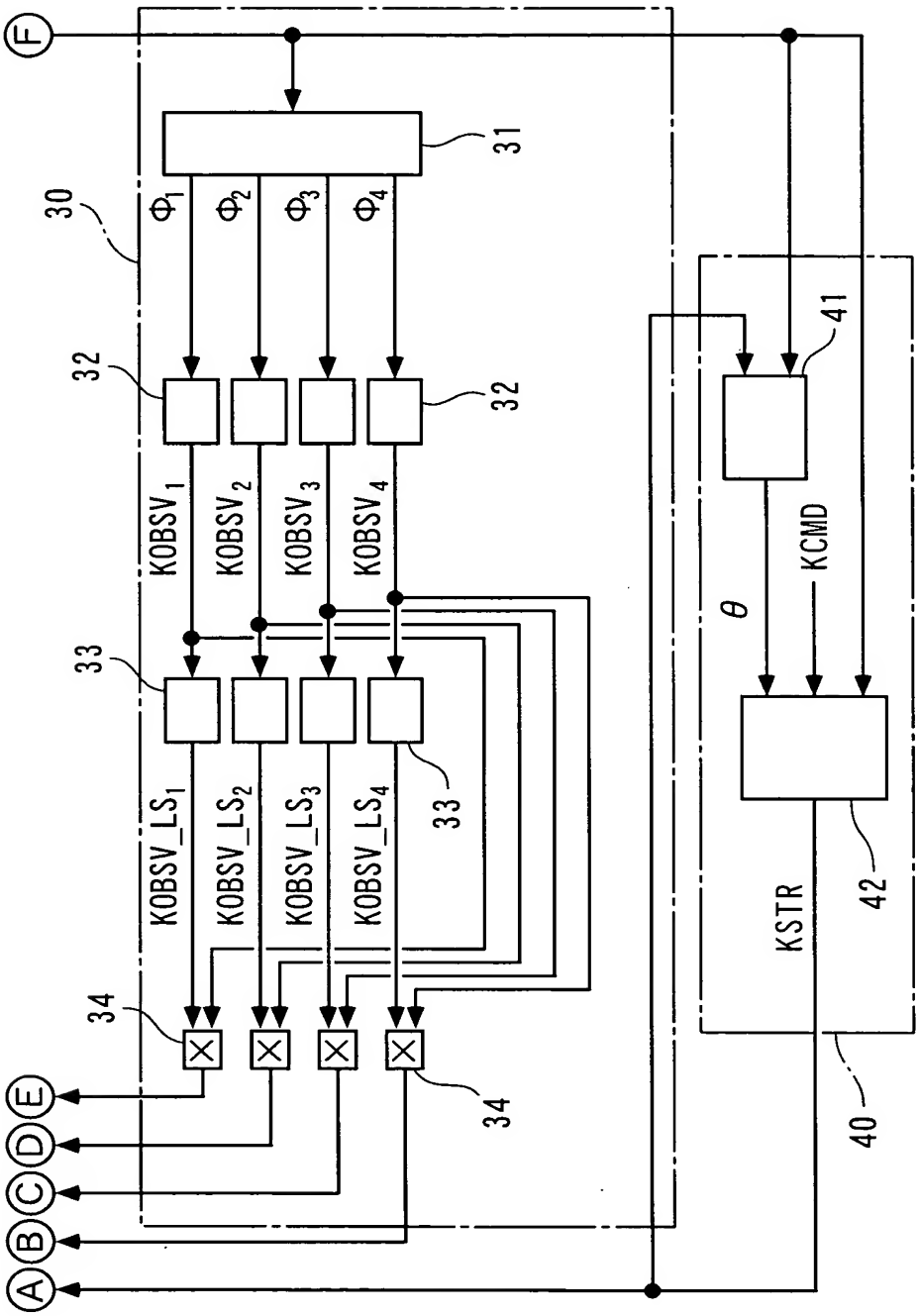
101
30
31
32
33
34
40
41
42
Φ1
Φ2
Φ3
Φ4
KOBSV_1
KOBSV_2
KOBSV_3
KOBSV_4
KOBSV_LS1
KOBSV_LS2
KOBSV_LS3
KOBSV_LS4
θ
KCMD
KSTR
Ⓐ
Ⓑ
Ⓒ
Ⓓ
Ⓔ
Ⓕ

FIG. 25

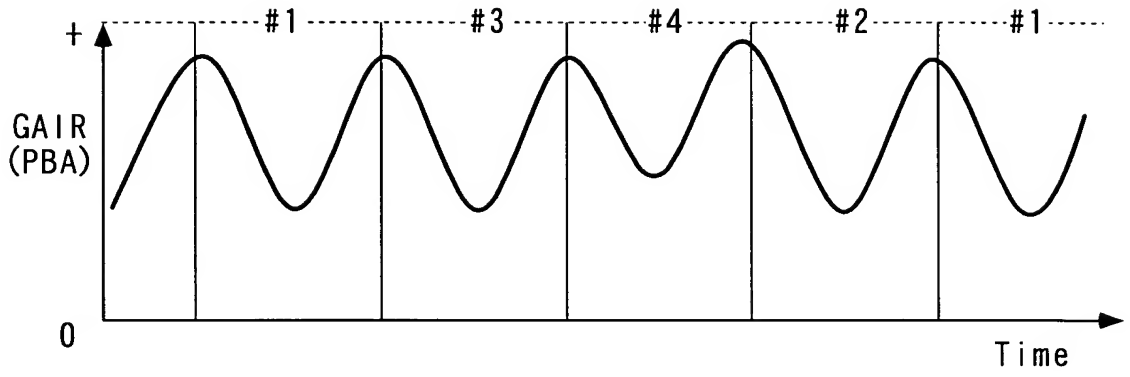
+
GAIR
(PBA)
0
#1
#3
#4
#2
#1
Time

FIG. 26

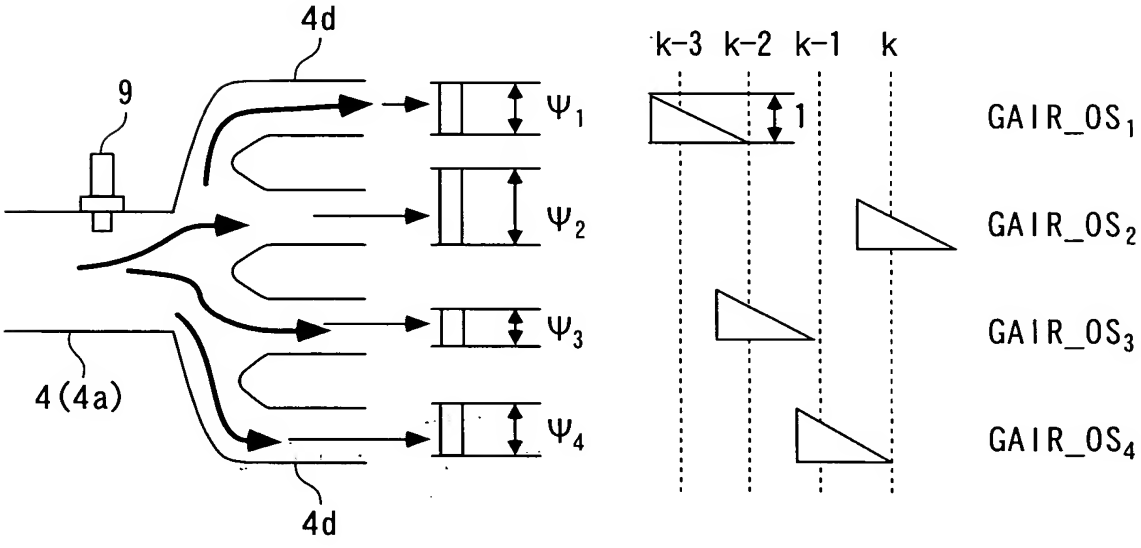
4d
9
Ψ1
Ψ2
Ψ3
Ψ4
4(4a)
4d
k-3 k-2 k-1 k
1
GAIR_OS1
GAIR_OS2
GAIR_OS3
GAIR_OS4

FIG. 27

$$GAIR(k-d') = \Psi_1(k) \cdot GAIR\_OS_1(k) + \Psi_2(k) \cdot GAIR\_OS_2(k) + \Psi_3(k) \cdot GAIR\_OS_3(k) + \Psi_4(k) \cdot GAIR\_OS_4(k) \quad \cdots\cdots (58)$$

$$GAIR\_EST(k) = \Psi_1(k) \cdot GAIR\_OS_1(k) + \Psi_2(k) \cdot GAIR\_OS_2(k) + \Psi_3(k) \cdot GAIR\_OS_3(k) + \Psi_4(k) \cdot GAIR\_OS_4(k) \quad \cdots\cdots (59)$$

$$\psi(k) = \psi(k-1) + KR(k) \cdot ide'(k) \quad \cdots\cdots (60)$$

$$\psi(k)^T = [\Psi_1(k),\ \Psi_2(k),\ \Psi_3(k),\ \Psi_4(k)] \quad \cdots\cdots (61)$$

$$ide'(k) = GAIR(k-d') - GAIR\_EST(k) \quad \cdots\cdots (62)$$

$$GAIR\_EST(k) = \psi(k-1)^T \cdot \zeta'(k) \quad \cdots\cdots (63)$$

$$\zeta'(k)^T = [GAIR\_OS_1(k),\ GAIR\_OS_2(k),\ GAIR\_OS_3(k),\ GAIR\_OS_4(k)] \quad \cdots\cdots (64)$$

$$KR(k) = \frac{R(k) \cdot \zeta'(k)}{1 + \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \quad \cdots\cdots (65)$$

$$R(k+1) = \frac{1}{\lambda_1''} \cdot \left(I - \frac{\lambda_2'' \cdot R(k) \cdot \zeta'(k) \cdot \zeta'(k)^T}{\lambda_1'' + \lambda_2'' \cdot \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \right) \cdot R(k) \quad \cdots\cdots (66)$$

I : UNIT MATRIX

λ_1'', λ_2'' : WEIGHTING PARAMETER

FIG. 28

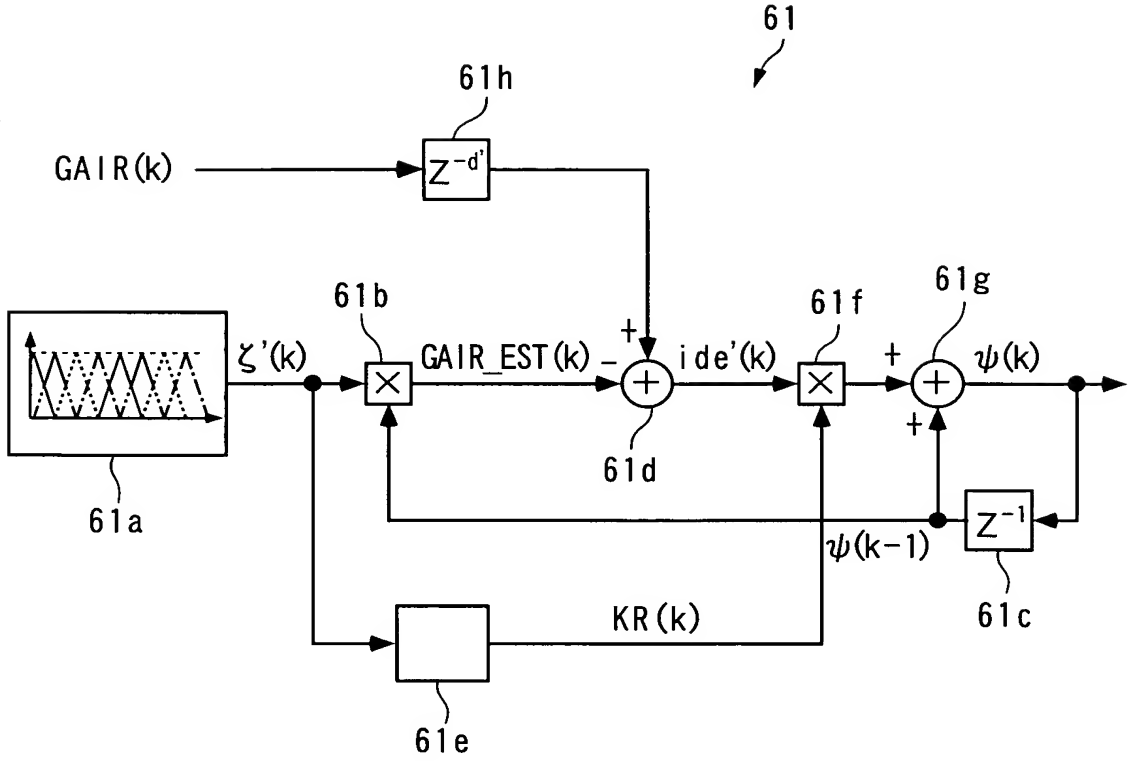
61
61h
GAIR(k)
$Z^{-d'}$
61b
61f
61g
ζ'(k)
GAIR_EST(k)
ide'(k)
ψ(k)
61d
61a
Z^{-1}
ψ(k-1)
61c
KR(k)
61e

FIG. 29

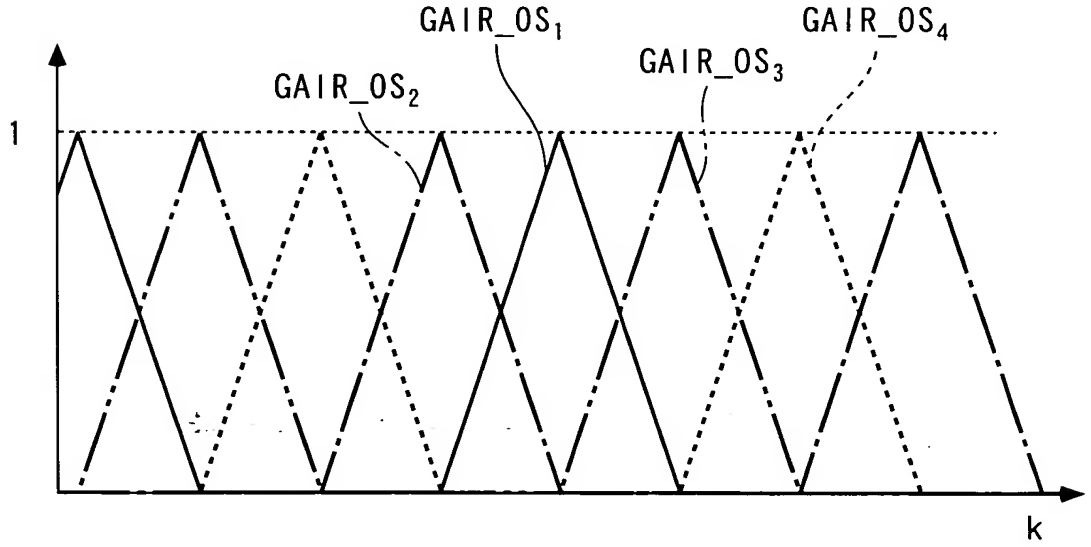
GAIR_OS1
GAIR_OS4
GAIR_OS3
GAIR_OS2
1
k

FIG. 30

$$\Psi ave(k) = \frac{1}{4} \cdot \left\{ \Psi_1(k) + \Psi_2(k) + \Psi_3(k) + \Psi_4(k) \right\} \quad \cdots\cdots (67)$$

$$KICYL_i(k) = -GI' \cdot \sum_{j=0}^{k} e'(j) - FI' \cdot \Psi_i(k) - HI' \cdot [\Psi_i(k) - \Psi_i(k-1)] \quad \cdots\cdots (68)$$

$$e'(k) = \Psi_i(k) - \Psi ave(k) \quad \cdots\cdots (69)$$

FI', GI', HI' : FEEDBACK GAINS

FIG. 31

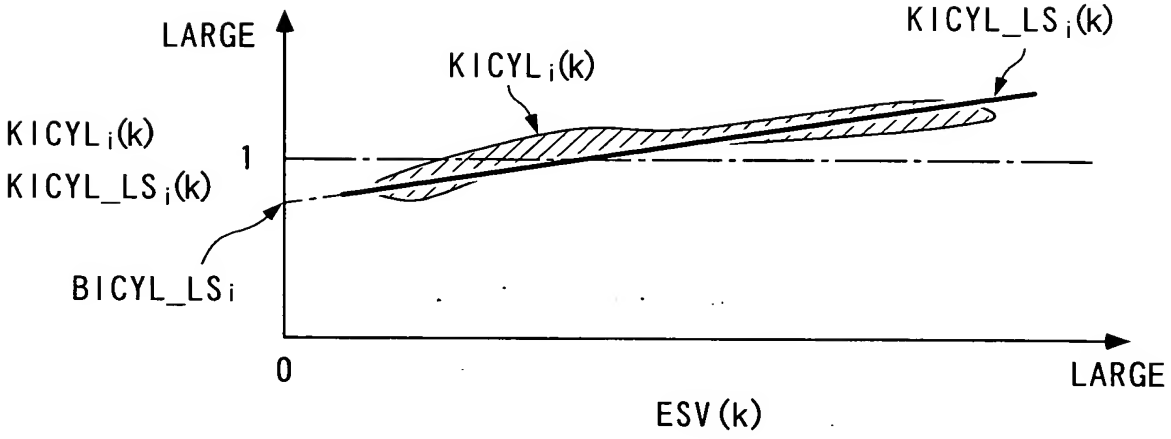

FIG. 32

$$KICYL\_LS_i = AICYL\_LS_i \cdot ESV(k) + BICYL\_LS_i \quad \cdots\cdots (70)$$

$$\theta ICYL\_LS_i(k) = \theta ICYL\_LS_i(k-1) + KU_i(k) \cdot Eic_i(k) \quad \cdots\cdots (71)$$

$$\theta ICYL\_LS_i(k)^T = [AICYL\_LS_i(k), BICYL\_LS_i(k)] \quad \cdots\cdots (72)$$

$$Eic_i(k) = KICYL_i(k) \cdot KICYL\_LS_i(k) - \theta ICYL\_LS_i(k-1)^T \cdot Z'(k) \quad \cdots\cdots (73)$$

$$KICYL\_LS_i(k) = \theta ICYL\_LS_i(k-1)^T \cdot Z'(k) \quad \cdots\cdots (74)$$

$$Z'(k)^T = [ESV(k), 1] \quad \cdots\cdots (75)$$

$$KU_i(k) = \frac{U_i(k) \cdot Z'(k)}{1 + Z'(k)^T \cdot U_i(k) \cdot Z'(k)} \quad \cdots\cdots (76)$$

$$U_i(k+1) = \frac{1}{\lambda_1^*} \cdot \left(I - \frac{\lambda_2^* \cdot U_i(k) \cdot Z'(k)^T \cdot Z'(k)}{\lambda_1^* + \lambda_2^* \cdot Z'(k)^T \cdot U_i(k) \cdot Z'(k)} \right) \cdot U_i(k) \quad \cdots\cdots (77)$$

I : UNIT MATRIX
λ_1^*, λ_2^* : WEIGHTING PARAMETER

$$KICYL\_LS_i(k) = \theta ICYL\_LS_i(k-1)^T \cdot Z'(k) = AICYL\_LS_i(k-1) \cdot ESV(K) + BICYL\_LS_i(k-1) \quad \cdots\cdots (78)$$

FIG. 33

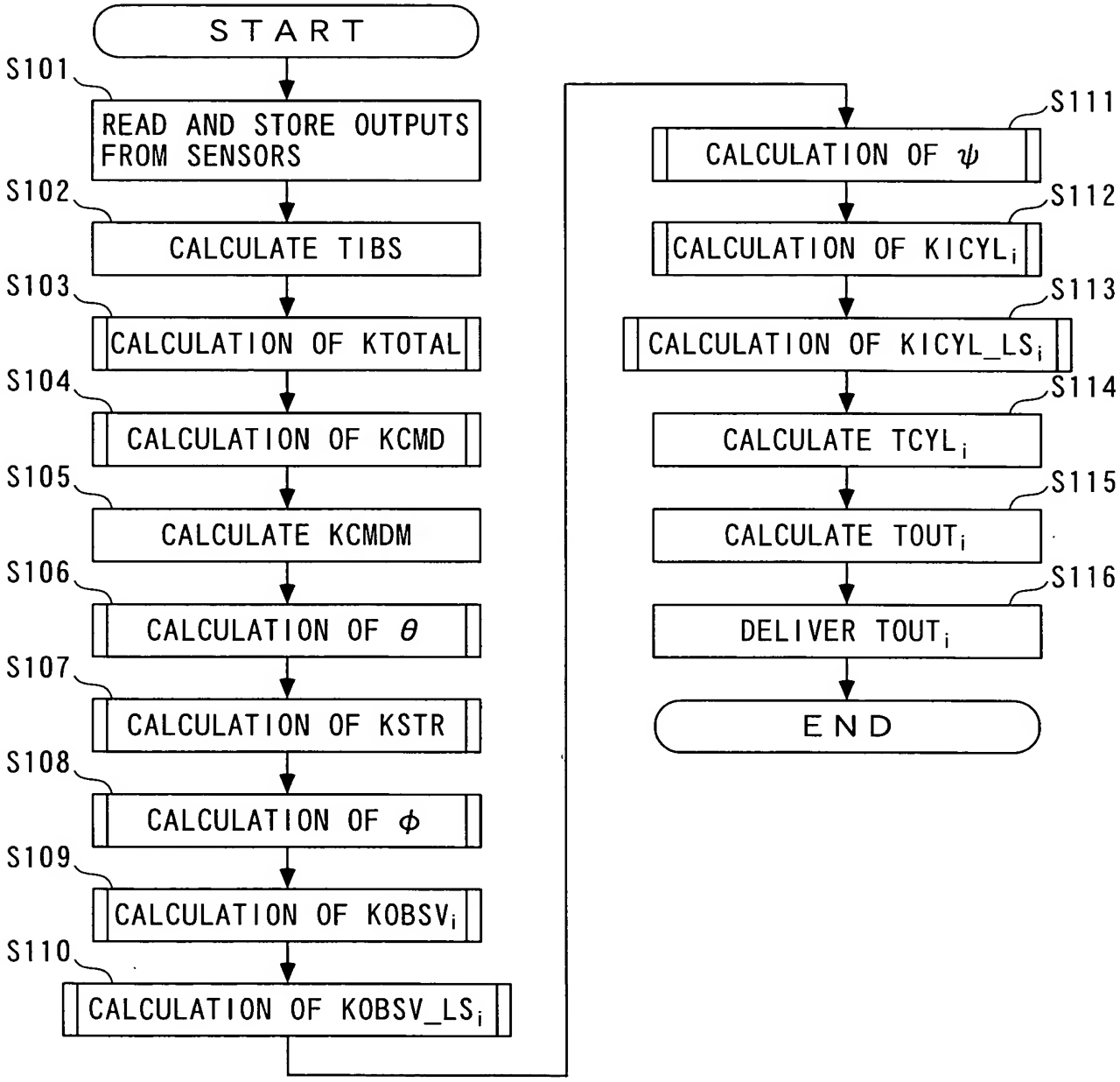
START
S101
READ AND STORE OUTPUTS FROM SENSORS
S102
CALCULATE TIBS
S103
CALCULATION OF KTOTAL
S104
CALCULATION OF KCMD
S105
CALCULATE KCMDM
S106
CALCULATION OF θ
S107
CALCULATION OF KSTR
S108
CALCULATION OF φ
S109
CALCULATION OF KOBSV$_i$
S110
CALCULATION OF KOBSV_LS$_i$
S111
CALCULATION OF ψ
S112
CALCULATION OF KICYL$_i$
S113
CALCULATION OF KICYL_LS$_i$
S114
CALCULATE TCYL$_i$
S115
CALCULATE TOUT$_i$
S116
DELIVER TOUT$_i$
END

FIG. 34

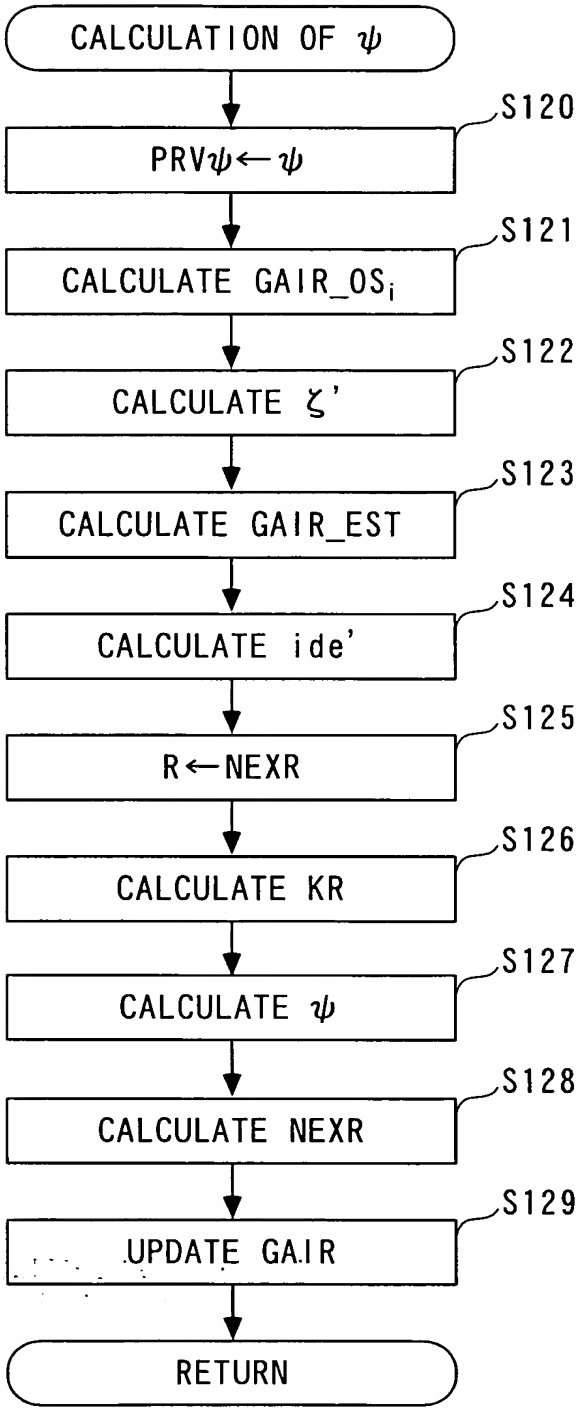
CALCULATION OF ψ
S120
PRVψ←ψ
S121
CALCULATE GAIR_OS$_i$
S122
CALCULATE ζ'
S123
CALCULATE GAIR_EST
S124
CALCULATE ide'
S125
R←NEXR
S126
CALCULATE KR
S127
CALCULATE ψ
S128
CALCULATE NEXR
S129
UPDATE GAIR
RETURN

FIG. 35

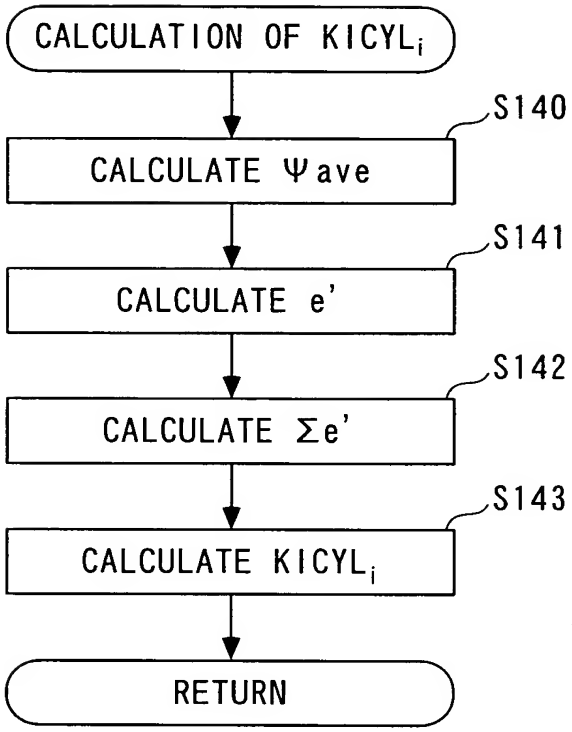
CALCULATION OF KICYL$_i$
S140
CALCULATE Ψave
S141
CALCULATE e'
S142
CALCULATE Σe'
S143
CALCULATE KICYL$_i$
RETURN

FIG. 36

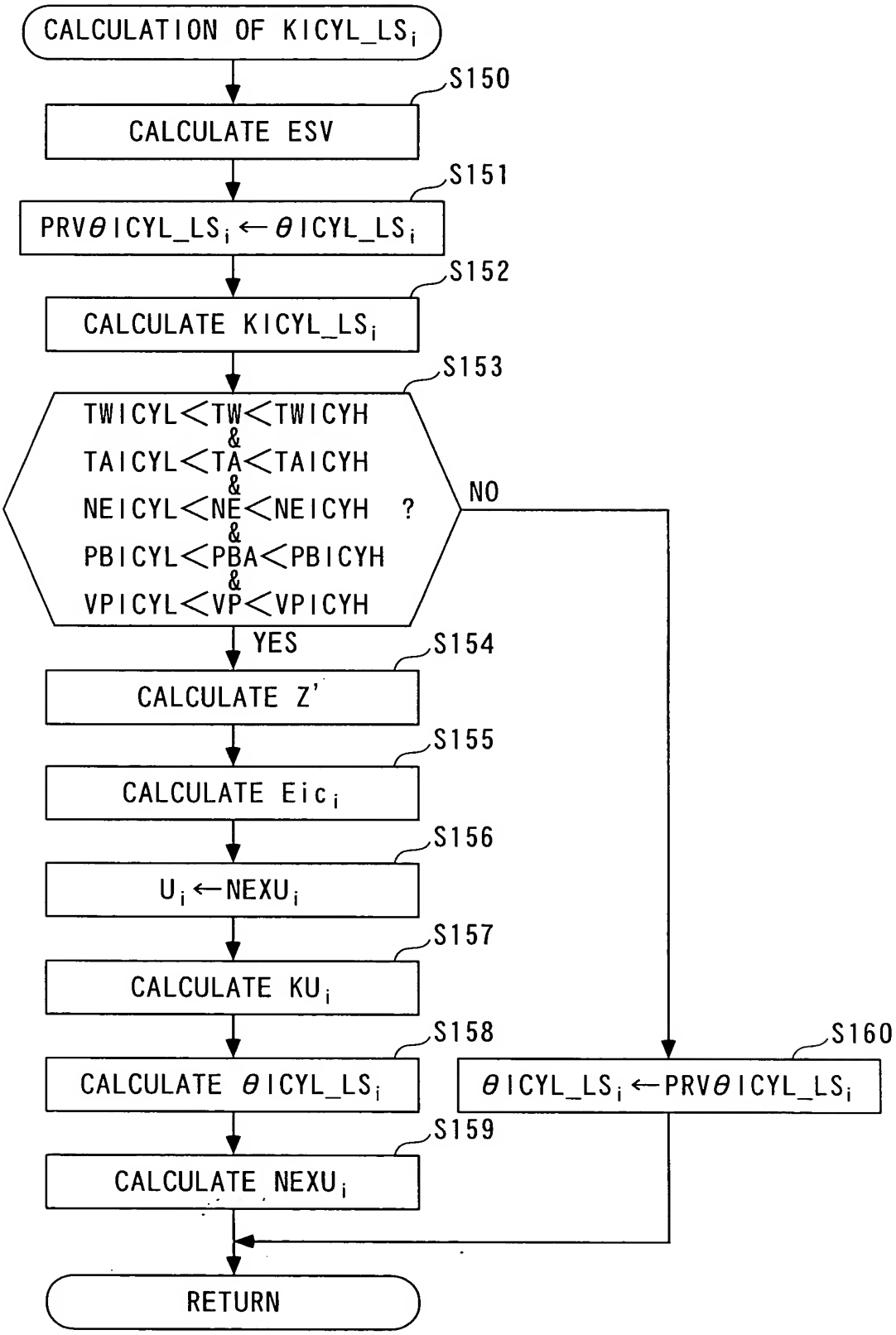
CALCULATION OF KICYL_LSi
S150
CALCULATE ESV
S151
PRVθICYL_LSi←θICYL_LSi
S152
CALCULATE KICYL_LSi
S153
TWICYL<TW<TWICYH
&
TAICYL<TA<TAICYH
&
NEICYL<NE<NEICYH ?
&
PBICYL<PBA<PBICYH
&
VPICYL<VP<VPICYH
NO
YES
S154
CALCULATE Z'
S155
CALCULATE Eici
S156
Ui←NEXUi
S157
CALCULATE KUi
S158
CALCULATE θICYL_LSi
S159
CALCULATE NEXUi
S160
θICYL_LSi←PRVθICYL_LSi
RETURN

FIG. 37

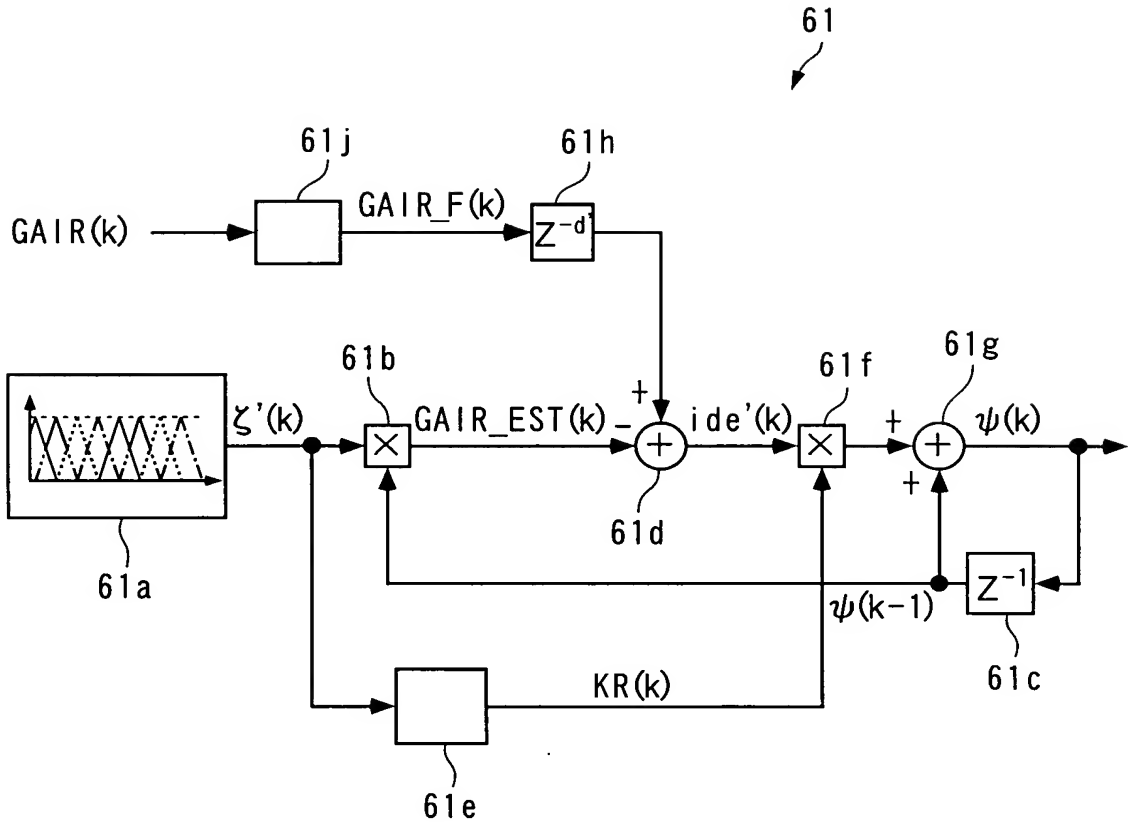
61
61j
61h
GAIR(k)
GAIR_F(k)
$Z^{-d'}$
61b
61f
61g
ζ'(k)
GAIR_EST(k)
+
−
ide'(k)
+
+
ψ(k)
61d
61a
Z^{-1}
ψ(k-1)
61c
KR(k)
61e

FIG. 38

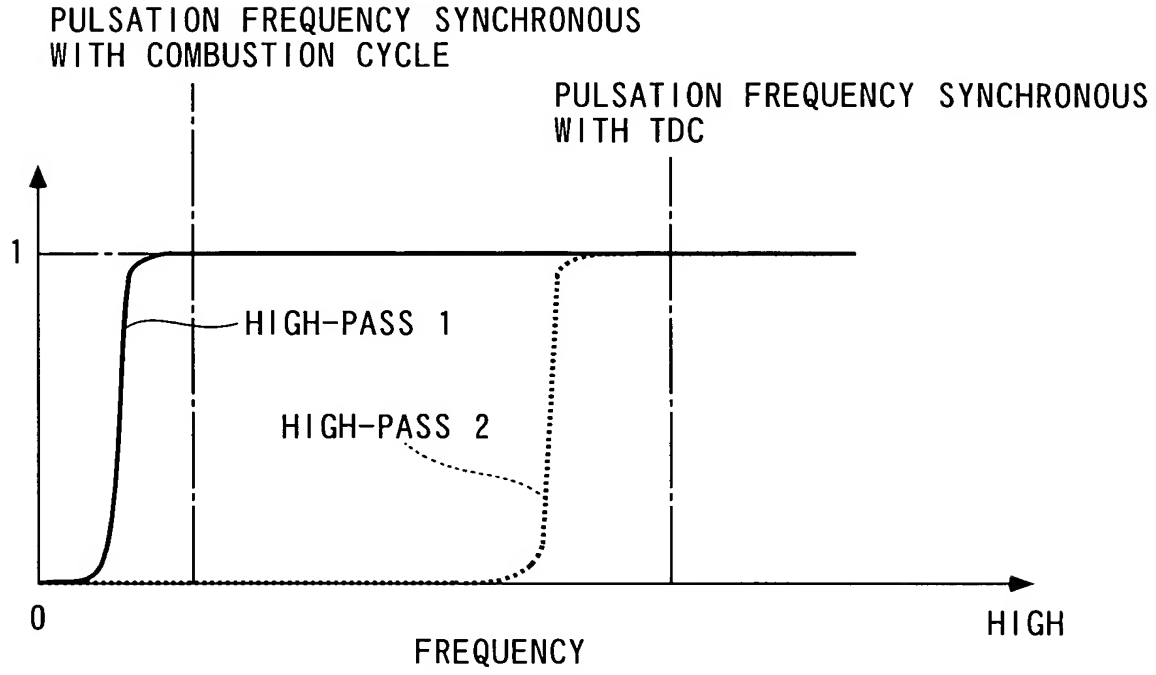
PULSATION FREQUENCY SYNCHRONOUS
WITH COMBUSTION CYCLE
PULSATION FREQUENCY SYNCHRONOUS
WITH TDC
1
HIGH-PASS 1
HIGH-PASS 2
0
HIGH
FREQUENCY

FIG. 39

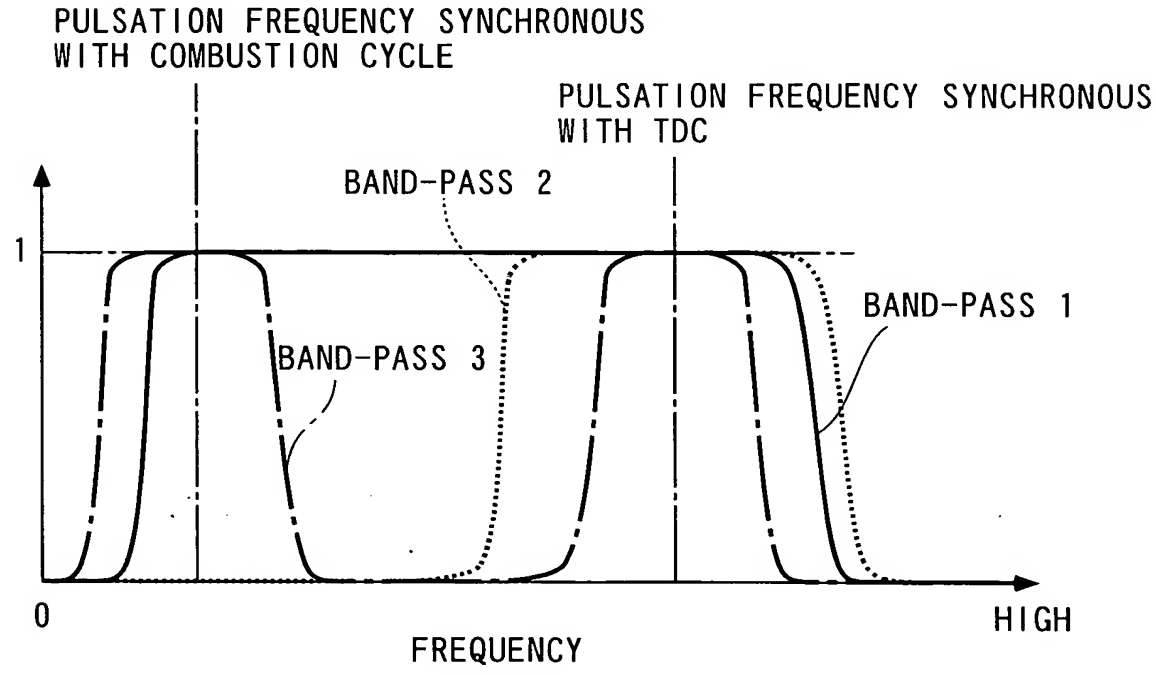
PULSATION FREQUENCY SYNCHRONOUS
WITH COMBUSTION CYCLE
PULSATION FREQUENCY SYNCHRONOUS
WITH TDC
BAND-PASS 2
1
BAND-PASS 1
BAND-PASS 3
0
HIGH
FREQUENCY

FIG. 40

$$GAIR\_F(k) = b0 \cdot GAIR(k) + b1 \cdot GAIR(k-1) + \ldots + bm^* \cdot GAIR(k-m^*) + a1 \cdot GAIR\_F(k-1) + a2 \cdot GAIR\_F(k-2) + \cdots + an^* \cdot GAIR\_F(k-n^*) \quad \cdots\cdots (79)$$

$$\psi(k) = \psi(k-1) + KR(k) \cdot ide'(k) \quad \cdots\cdots (80)$$

$$\psi(k)^T = [\Psi_1(k),\ \Psi_2(k),\ \Psi_3(k),\ \Psi_4(k)] \quad \cdots\cdots (81)$$

$$ide'(k) = GAIR\_F(k-d') - GAIR\_EST(k) \quad \cdots\cdots (82)$$

$$GAIR\_EST(k) = \psi(k-1)^T \cdot \zeta'(k) \quad \cdots\cdots (83)$$

$$\zeta'(k)^T = [GAIR\_OS_1(k),\ GAIR\_OS_2(k),\ GAIR\_OS_3(k),\ GAIR\_OS_4(k)] \quad \cdots\cdots (84)$$

$$KR(k) = \frac{R(k) \cdot \zeta'(k)}{1 + \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \quad \cdots\cdots (85)$$

$$R(k+1) = \frac{1}{\lambda_1''} \cdot \left(I - \frac{\lambda_2'' \cdot R(k) \cdot \zeta'(k) \cdot \zeta'(k)^T}{\lambda_1'' + \lambda_2'' \cdot \zeta'(k)^T \cdot R(k) \cdot \zeta'(k)} \right) \cdot R(K) \quad \cdots\cdots (86)$$

I : UNIT MATRIX
λ_1'', λ_2'' : WEIGHTING PARAMETER

FIG. 41

IP-D CONTROL ALGORITHM

$$KICYL_i(k) = -GD' \cdot \sum_{j=0}^{k} e'(j) - FD' \cdot e'(k) - HD' \cdot [\Psi_i(k) - \Psi_i(k-1)] \quad \cdots\cdots (87)$$

$$e'(k) = \Psi_i(k) - \Psi ave(k) \quad \cdots\cdots (88)$$

FD', GD', HD' : FEEDBACK GAINS

RESPONSE-SPECIFIED CONTROL ALGORITHM

$$KICYL_i(k) = -FS' \cdot \sigma(k) - GS' \cdot \sum_{j=0}^{k} \cdot \sigma'(j) - HS' \cdot e(k) \quad \cdots\cdots (89)$$

$$e'(k) = \Psi_i(k) - \Psi ave(k) \quad \cdots\cdots (90)$$

$$\sigma'(k) = e'(k) + S' \cdot e'(k-1) \quad \cdots\cdots (91)$$

$\sigma'(k)$: SWITCHING FUNCTION
FS', GS', HS' : FEEDBACK GAINS
S' : SWITCHING FUNCTION SETTING PARAMETER ($-1 < S' < 1$)

FIG. 42

$$\psi(k) = \psi base + d\psi(k) \quad \cdots\cdots (92)$$

$$\psi base^T = [\Psi base_1, \Psi base_2, \Psi base_3, \Psi base_4] \quad \cdots\cdots (93)$$

$$d\psi(k) = \delta' \cdot d\psi(k-1) + KR(k) \cdot ide'(k) \quad \cdots\cdots (94)$$

$$ide'(k) = GAIR(k) - GAIR\_EST(k) \quad \cdots\cdots (95)$$

$$GAIR\_EST(k) = \psi(k-1)^T \cdot \zeta'(k) \quad \cdots\cdots (96)$$

$$\zeta'(k)^T = [GAIR\_OS_1(k-d'), GAIR\_OS_2(k-d'), GAIR\_OS_3(k-d'), GAIR\_OS_4(k-d')] \quad \cdots\cdots (97)$$

$$KR(k) = \frac{Pc' \cdot \zeta'(k)}{1 + \zeta'(k)^T \cdot Pc' \cdot \zeta'(k)} \quad \cdots\cdots (98)$$

Pc' : IDENTIFICATION GAIN

$$\delta' = \begin{bmatrix} \delta 1' & 0 & 0 & 0 \\ 0 & \delta 1' & 0 & 0 \\ 0 & 0 & \delta 1' & 0 \\ 0 & 0 & 0 & \delta 1' \end{bmatrix} \quad (0 < \delta 1' \leqq 1) \quad \cdots\cdots (99)$$

δ' : FORGETTING VECTOR

FIG. 43